WT-370

This document consists of 335 plus
4 pages (counting all preliminary
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OPERATION JANGLE

GAMMA RADIATION MEASUREMENTS

Project 2.1a   Gamma Radiation as a Function of Time and Distance
                (WT-329)

Project 2.1b   Gamma Radiation as a Function of Time with Droppable
                Telemeters (WT-392)

X Project 2.1c-1 Aerial Survey of Distant Contaminated Terrain (WT-330)

X Project 2.1c-2 Aerial Survey of Local Contaminated Terrain (WT-351)

Project 2.1d   Monitor Survey of Ground Contamination (WT-381)

X Project 2.3-1   Total Gamma Radiation Dosage (WT-331)

Project 2.3-2   Foxhole Shielding of Gamma Radiation (WT-393)

UNCLASSIFIED

OPERATION JANGLE

PROJECT 2.1a

GAMMA RADIATION AS A FUNCTION

OF

TIME AND DISTANCE

by

L. Costrell

Radiation Physics Laboratory

April 1, 1952

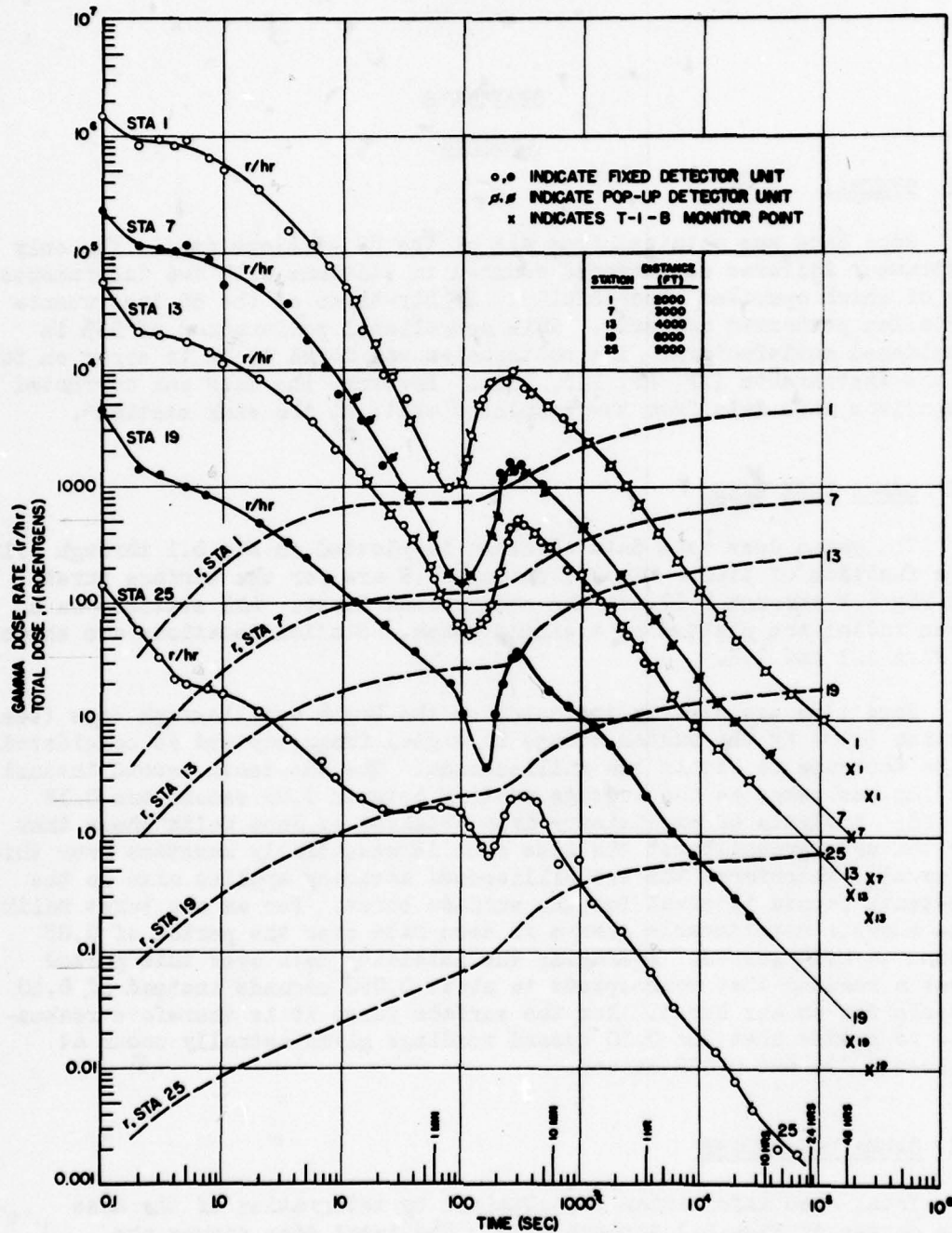National Bureau of Standards

Washington 25, D. C.

PROJECT 2.1a

Fig 6.1 Surface Burst, Dose Rate and Total Dose vs Time
(Dose received in first 0.1 second not included.
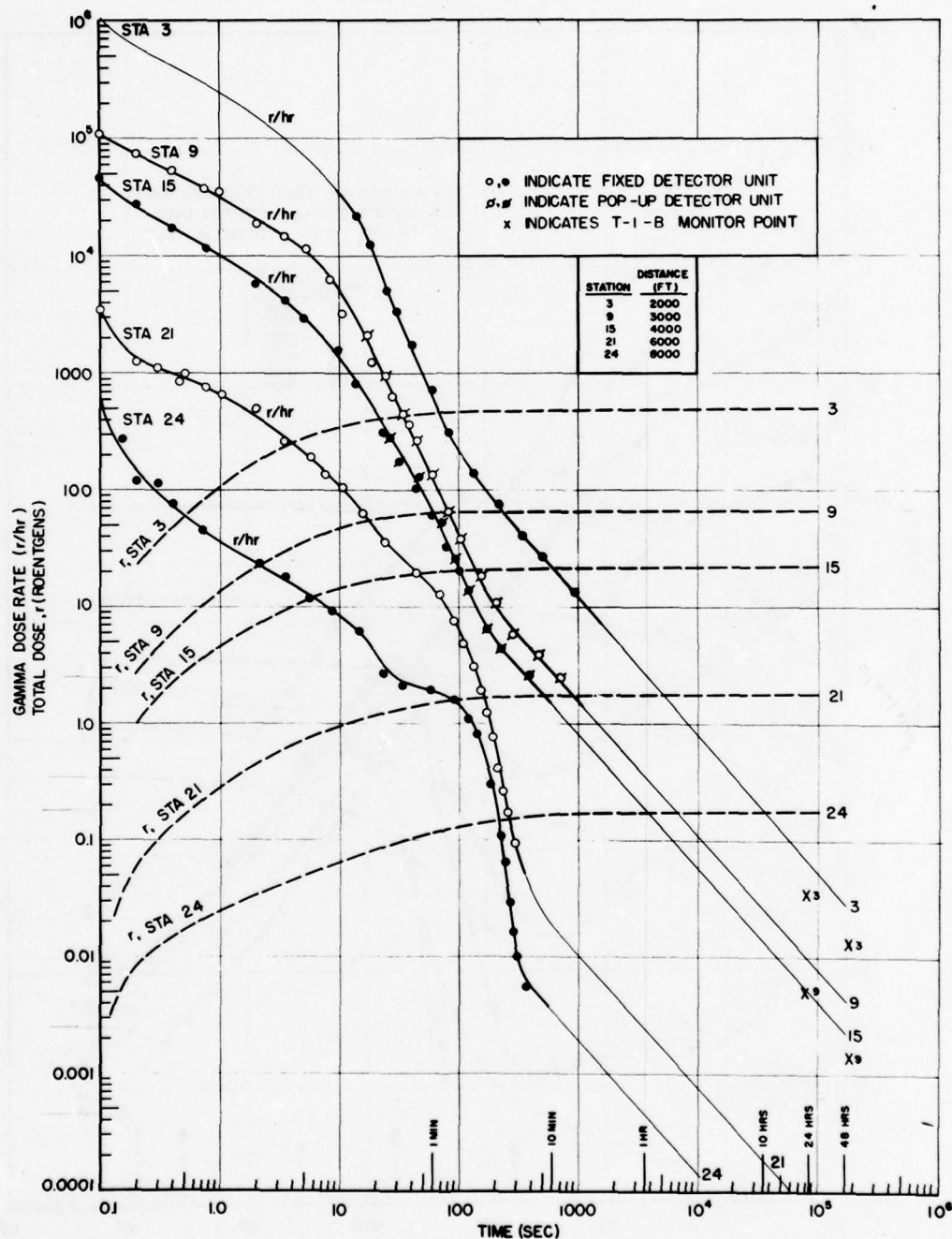See para 6.3. Station locations on Fig 1.1.)

- 52 -

PROJECT 2.1a

Fig 6.3 Surface Burst, Dose Rate and Total Dose vs Time
(Dose received in first 0.1 second not included.
See para 6.3. Station locations on Fig 1.1.)

- 54 -

PROJECT 2.1a

Fig 6.7 Underground Burst, Dose Rate and Total Dose vs Time
(Dose received in first 0.1 second not included.
See para 6.3. Station locations on Fig 1.2.)
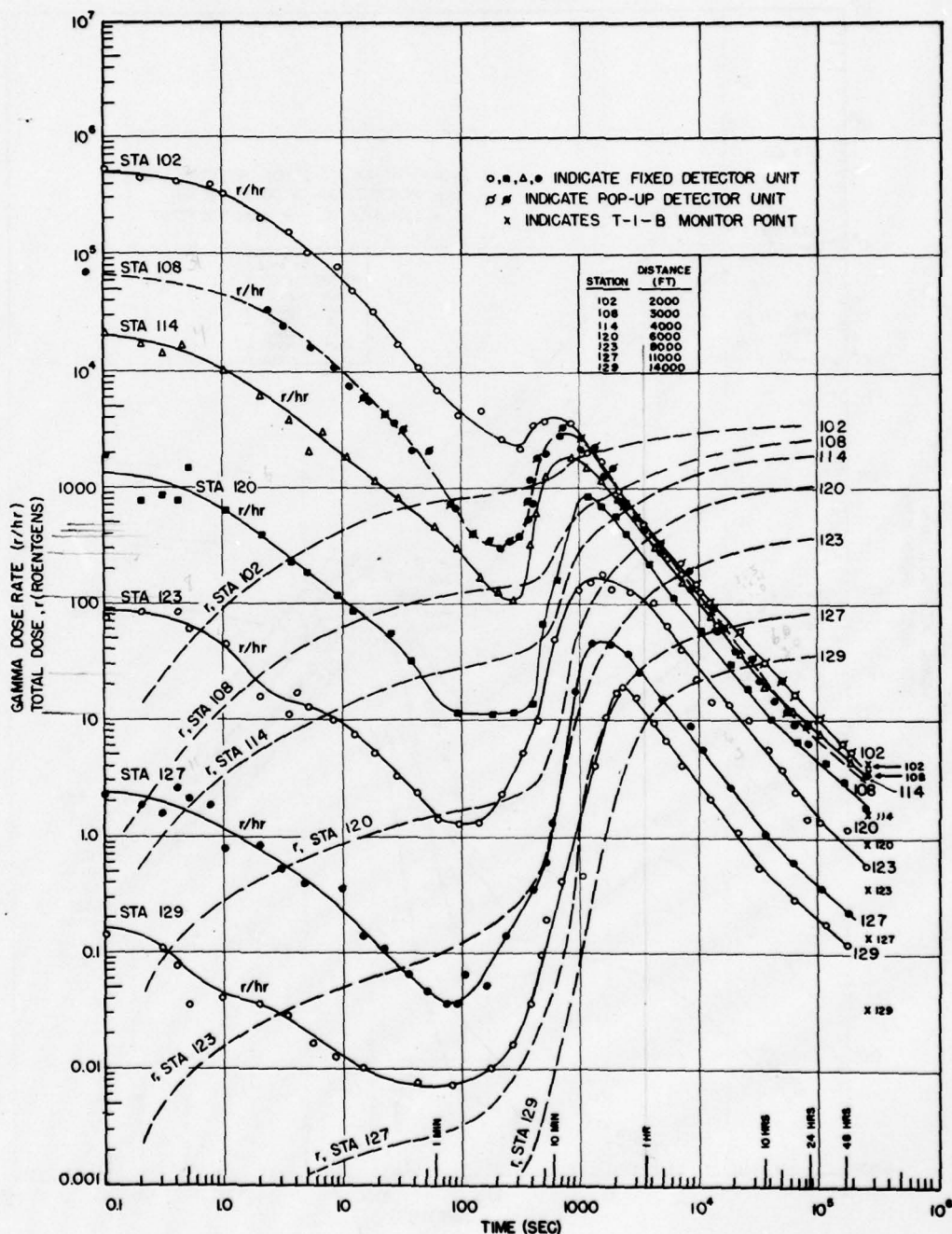
PROJECT 2.1a

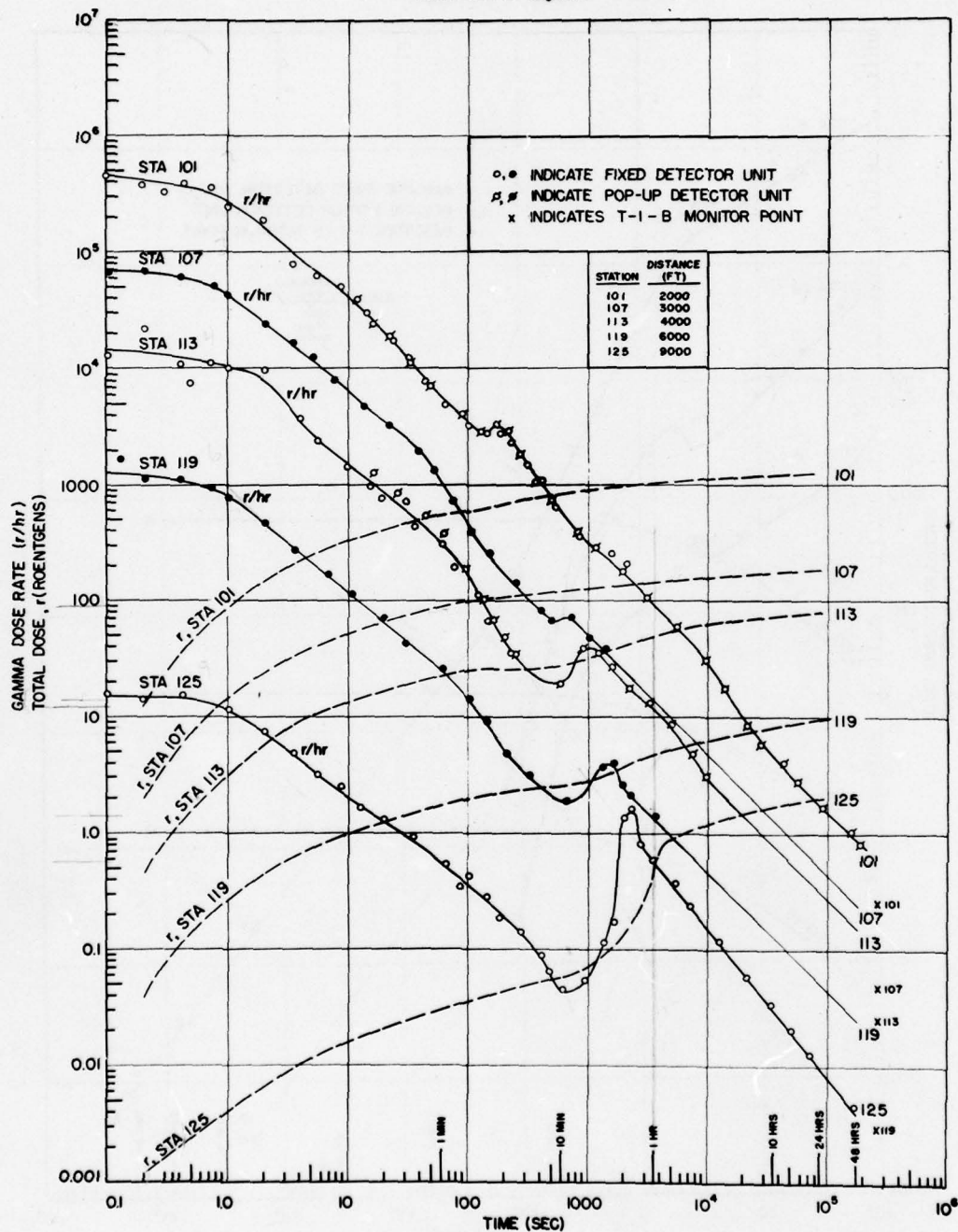

Fig 6.8 Underground Burst, Dose Rate and Total Dose vs Time
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See para 6.3. Station locations on Fig 1.2.)
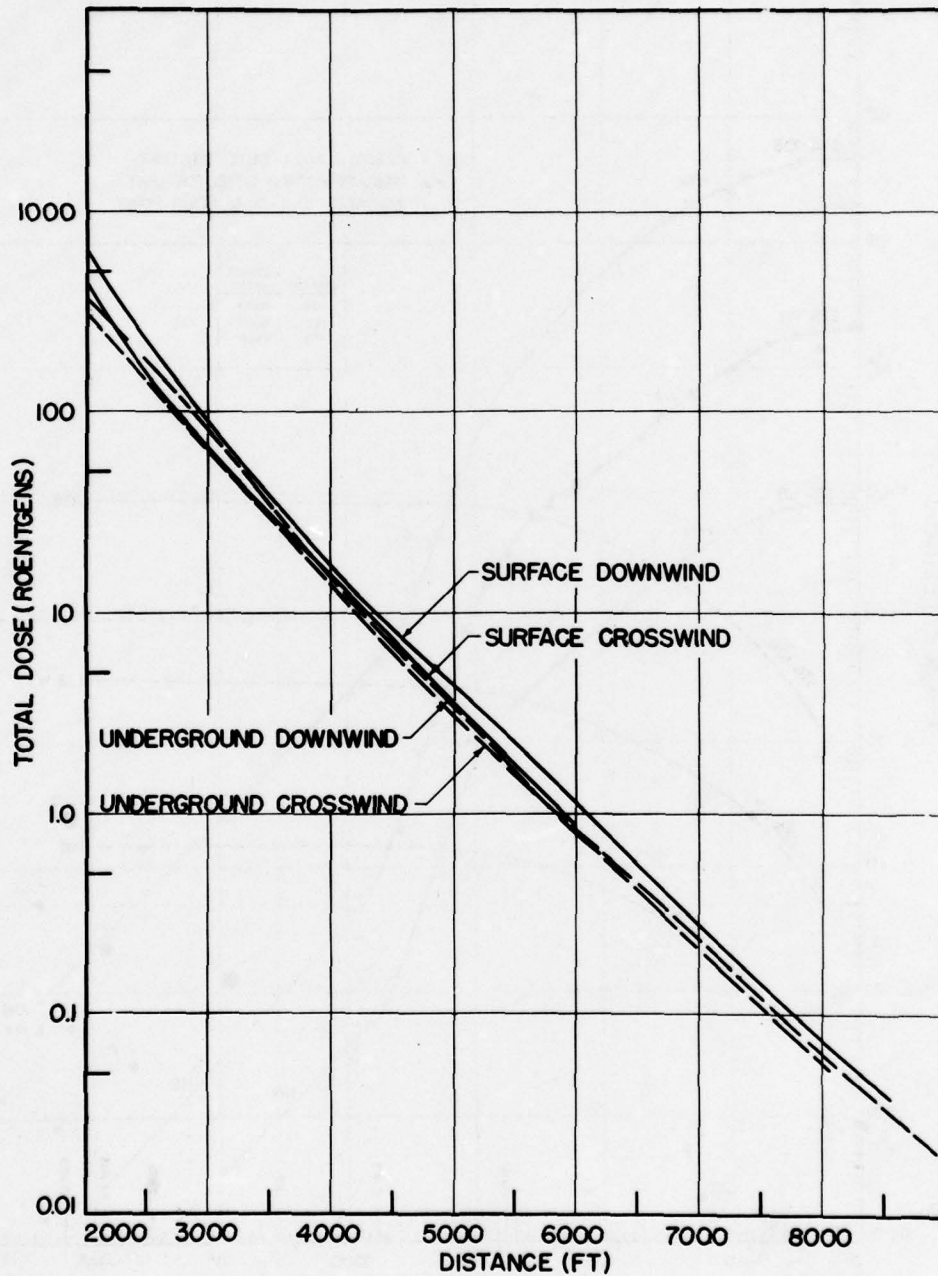
PROJECT 2.1a

Fig 6.13 Surface and Underground Burst Total Dose at 10 Seconds
(Dose received in first 0.1 second not included.)
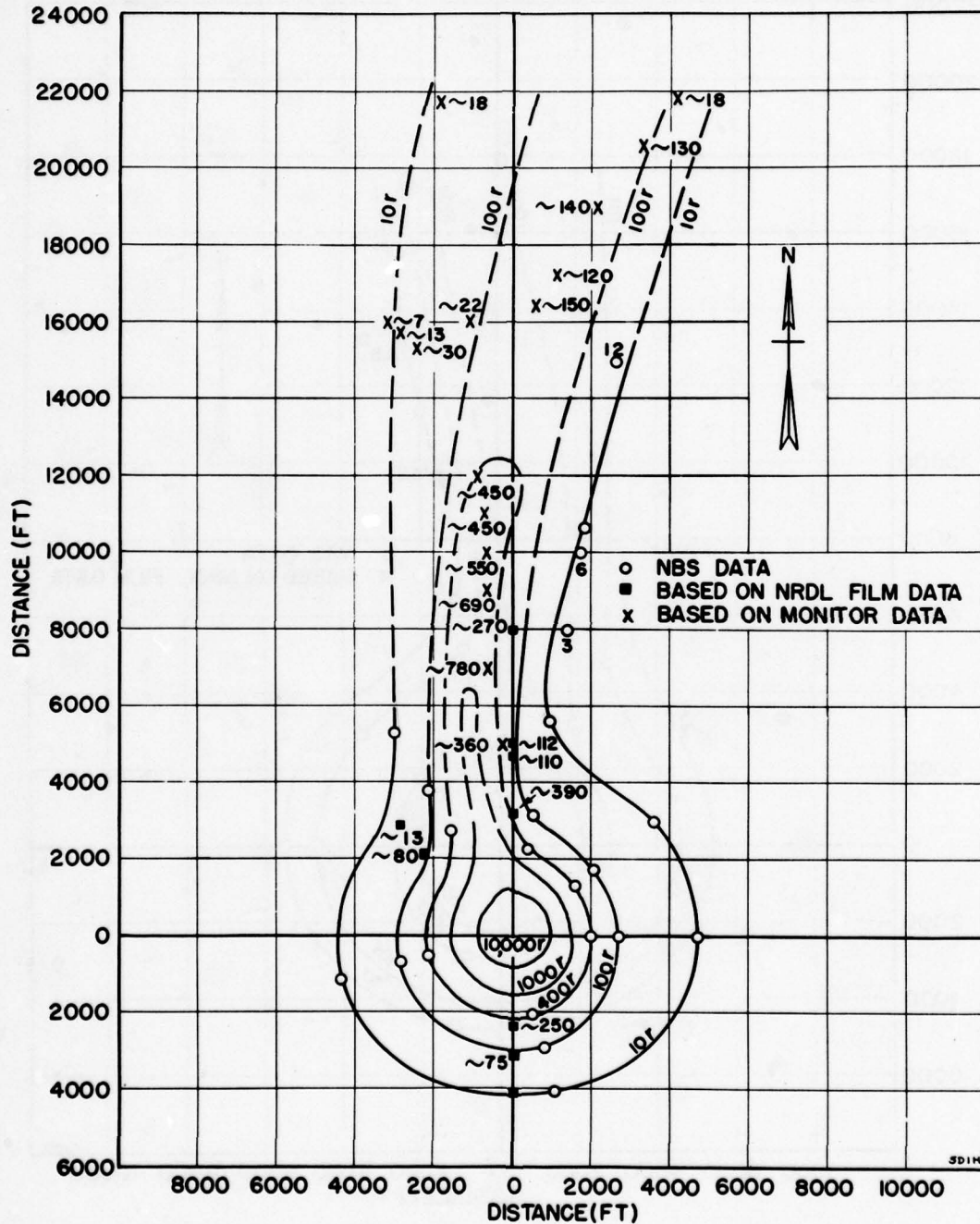
PROJECT 2.1a

Fig 6.15 Surface Burst, Iso-Dose Contours at 1 Hour
(Dose received in first 0.1 second not included.)
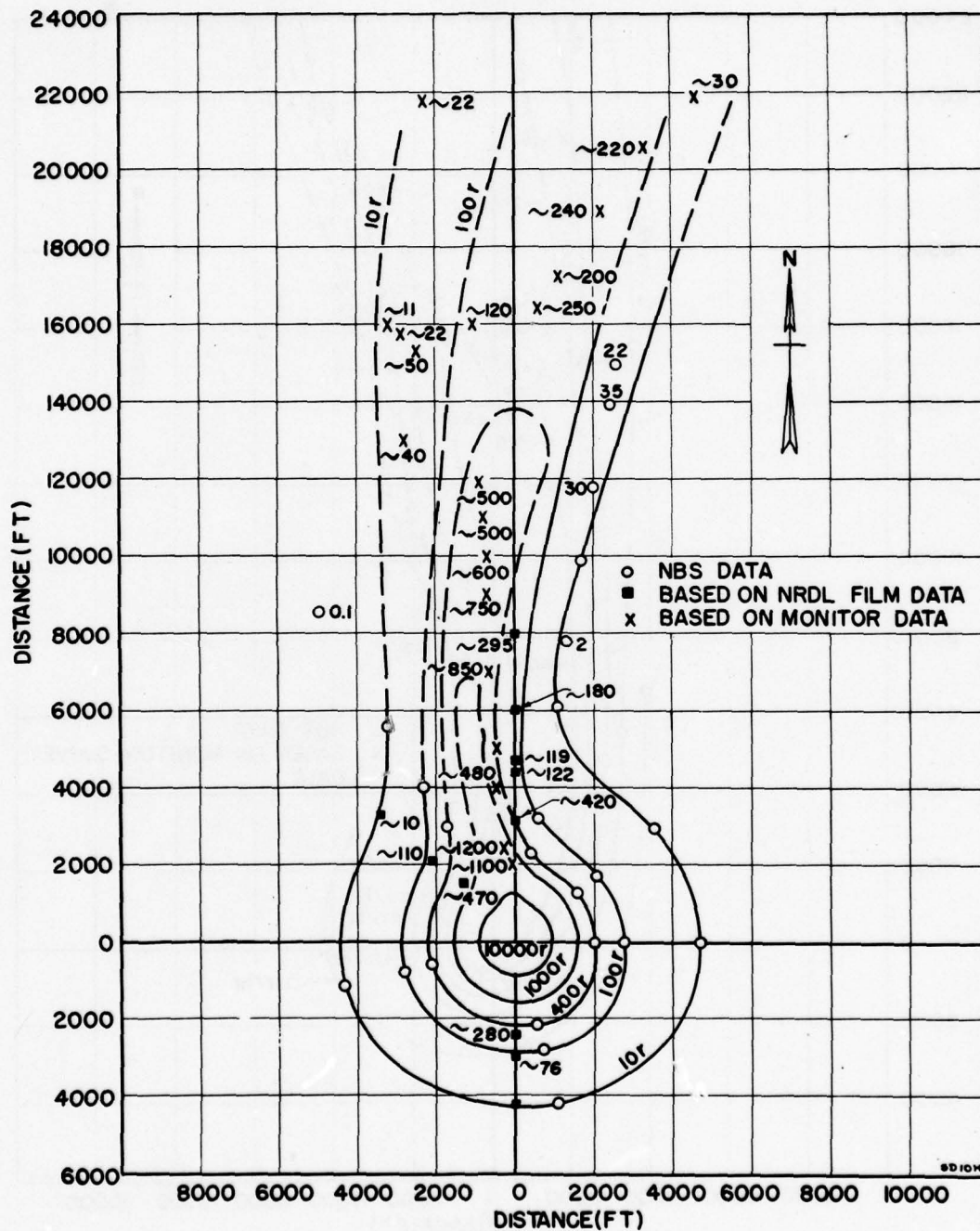
PROJECT 2.1a

Fig 6.16 Surface Burst, Iso-Dose Contours at 10 Hours
(Dose received in first 0.1 second not included.)
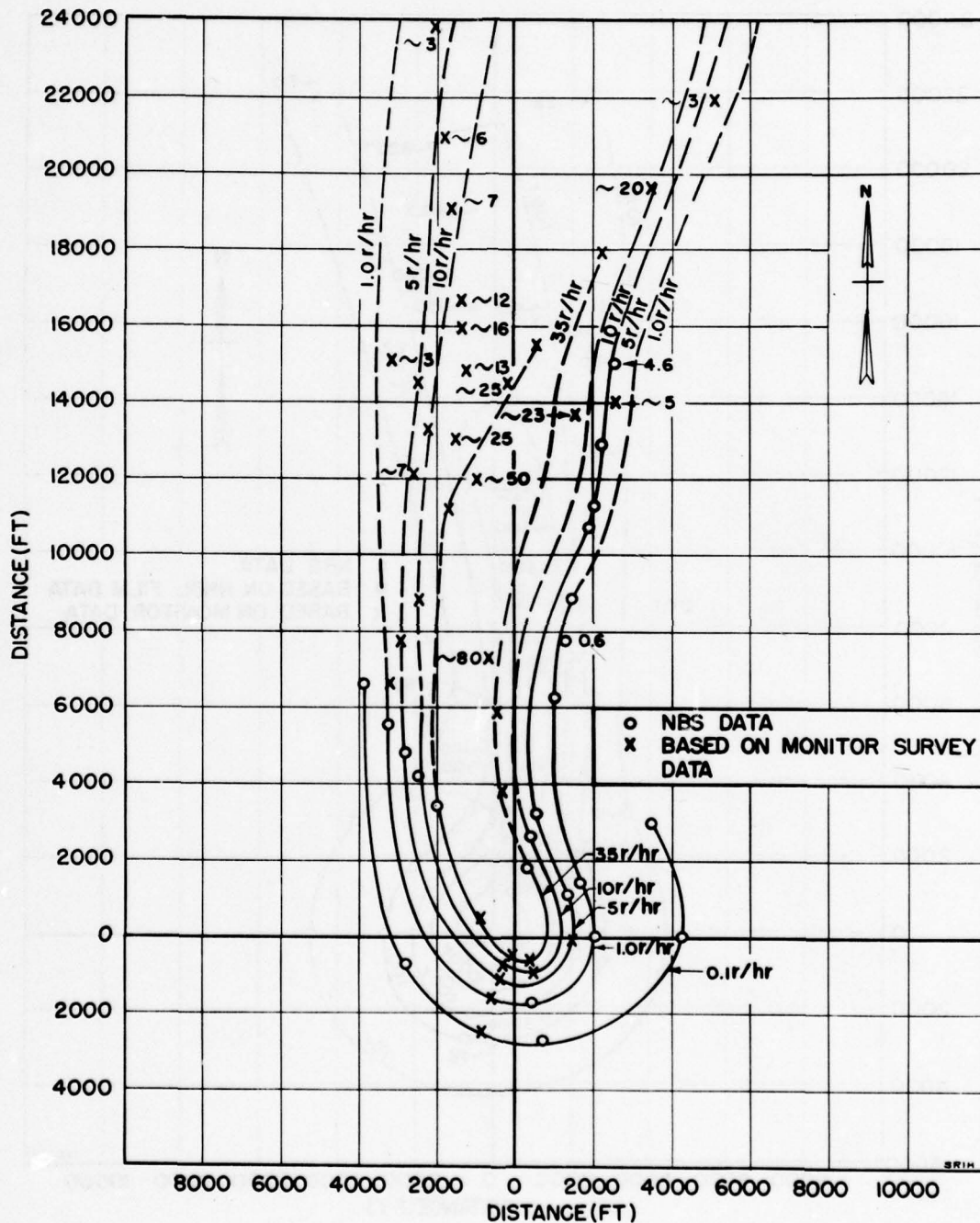
PROJECT 2.1a

Fig 6.17 Surface Burst, Iso-Rate Contours at 1 Hour
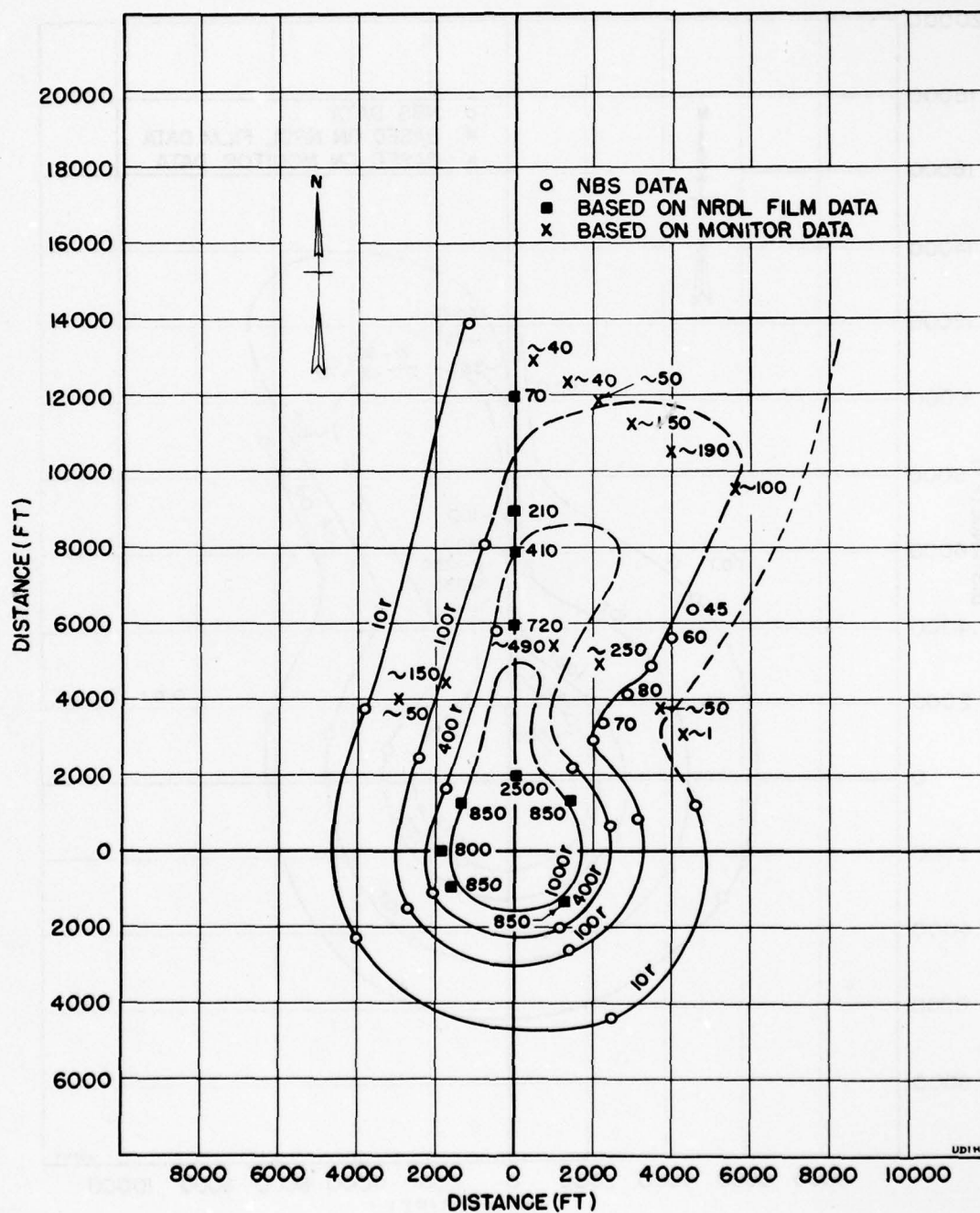
PROJECT 2.1a

Fig 6.19 Underground Burst, Iso-Dose Contours at 1 Hour
(Dose received in first 0.1 second not included.)

PROJECT 2.1a
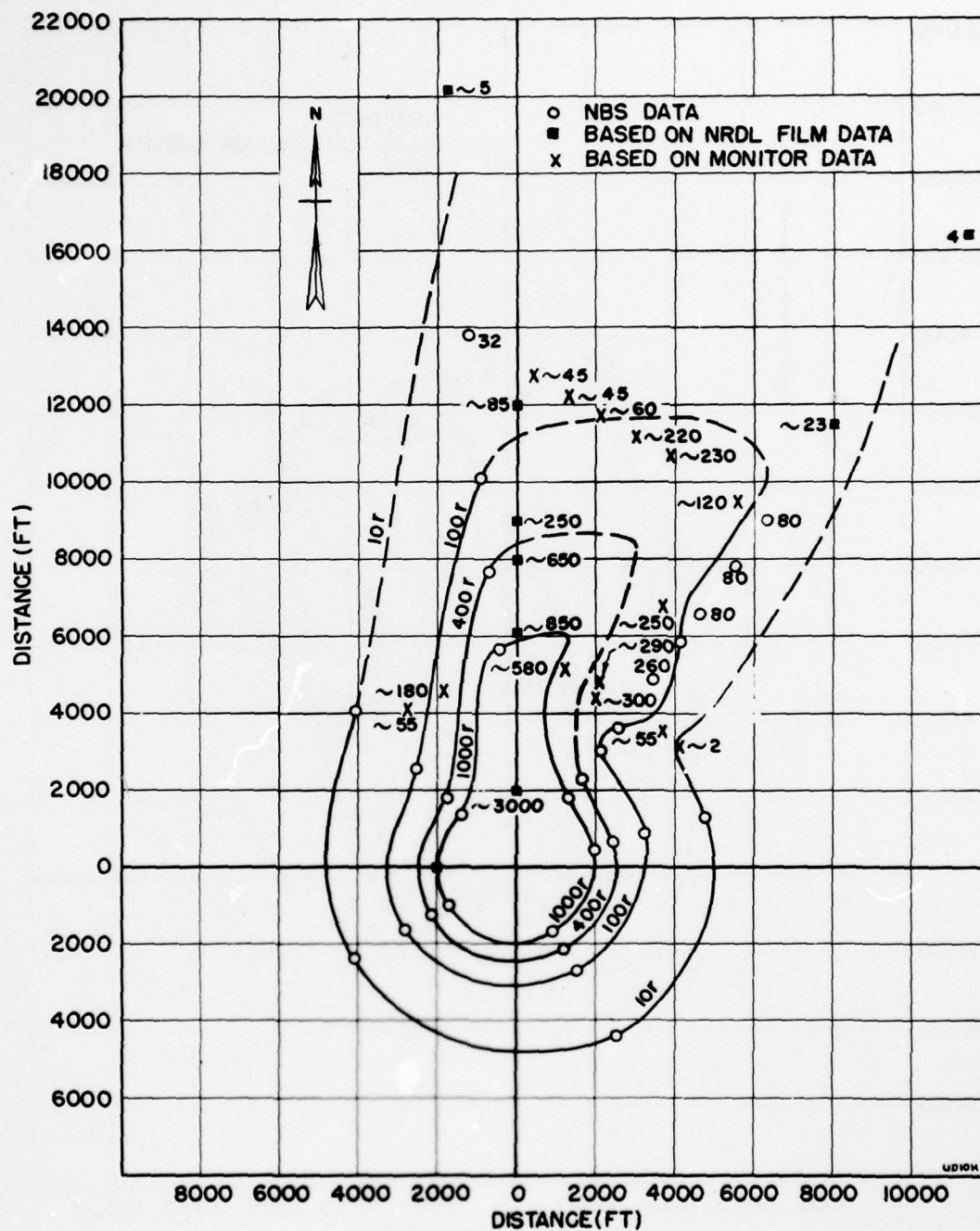
Fig 6.20 Underground Burst, Iso-Dose Contours at 10 Hours
(Dose received in first 0.1 second not included.)

- 71 -

APPENDIX D

WIND DATA

To aid in analysis of the contours presented in the text, the following wind velocity information is given.

TABLE D.1

Conditions at the Time of the Surface Burst

Height (ft)	Direction (Degrees)	Speed (mph)
0	190	2.3
6000	170	15.0
10000	200	36.8
14000	210	46.0

TABLE D.2

Conditions at the Time of the Underground Burst

Height (ft)	Direction (Degrees)	Speed (mph)
0	210	4.6
6000	190	5.8
10000	230	24.2
14000	250	28.8

APPENDIX E

AREAS WITHIN CONTOURS

The areas included within iso-dose and iso-rate lines on the various contours are shown in the tables below.

TABLE E.1

Surface Burst, Iso-Dose Contours at 10 Minutes

Value of iso-dose line (roentgens)	Included area (sq. miles)
400	greater than 0.6
100	" " 3.
10	" " 4.
3	" " 6.

TABLE E.2

Surface Burst, Iso-Dose Contours at 1 Hour

Value of iso-dose line (roentgens)	Included area (sq. miles)
10,000	0.10
1,000	0.38
400	1.0
100	greater than 3.
10	" " 6.

PROJECT 2.1a

TABLE E.3

Surface Burst, Iso-Dose Contours at 10 Hours

Value of iso-dose line (roentgens)	Included area (sq. miles)
10,000	0.10
1,000	0.43
400	1.2
100	greater than 3.
10	" " 6.

TABLE E.4

Surface Burst, Iso-Rate Contours at 1 Hour

Value of iso-rate line (roentgens/hr.)	Included area (sq. miles)
35	greater than 1
10	" " 3
5	" " 4
1	" " 6
0.1	" " 8

TABLE E.5

Underground Burst, Iso-Dose Contours at 10 Minutes

Value of iso-dose line (roentgens)	Included area (sq. miles)
400	0.70
100	1.9
10	4.2
1	greater than 6.

PROJECT 2.1a

TABLE E.6

Underground Burst, Iso-Dose Contours at 1 Hour

Value of iso-dose line (roentgens)	Included area (sq. miles)
1,000	0.47
400	1.1
100	2.7
10	greater than 6.

TABLE E.7

Underground Burst, Iso-Dose Contours at 10 Hours

Value of iso-dose line (roentgens)	Included area (sq. miles)
1,000	0.70
400	1.4
100	3.0
10	greater than 8.

TABLE E.8

Underground Burst, Iso-Rate Contours at 1 Hour

Value of iso-dose line (roentgens/hr)	Included area (sq. miles)
100	1.7
10	greater than 5.
1	" " 7.
0.1	" " 8.

OPERATION JANGLE

PROJECT 2.1c-2

AERIAL SURVEY OF LOCAL CONTAMINATED TERRAIN

by

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DEPARTMENT OF THE NAVY
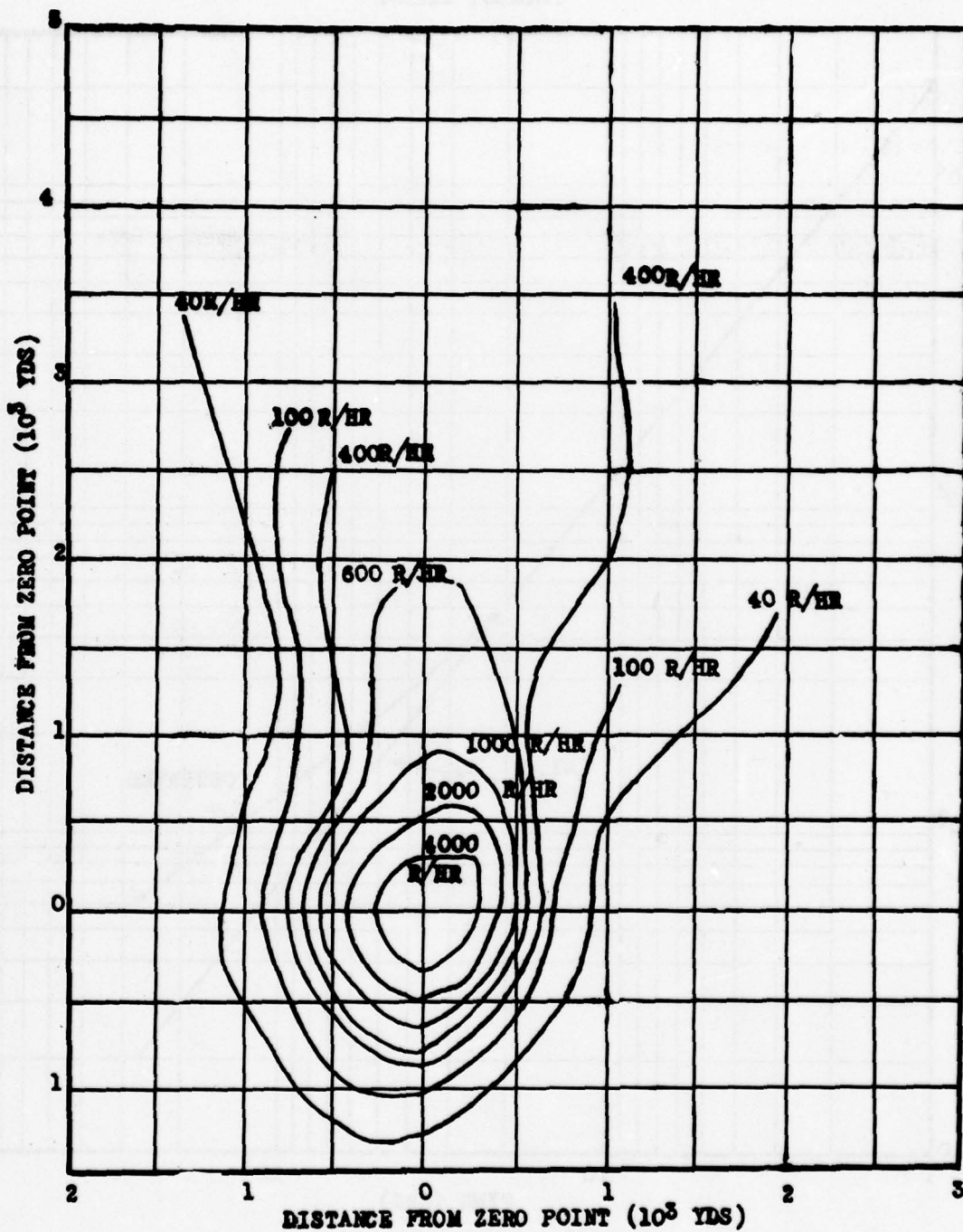
PROJECT 2.1c-2

Fig. 4.3 Gamma Intensity Contour Map at H+1 Hour Measured by AN/ADR-4
Surface Shot

- 36 -
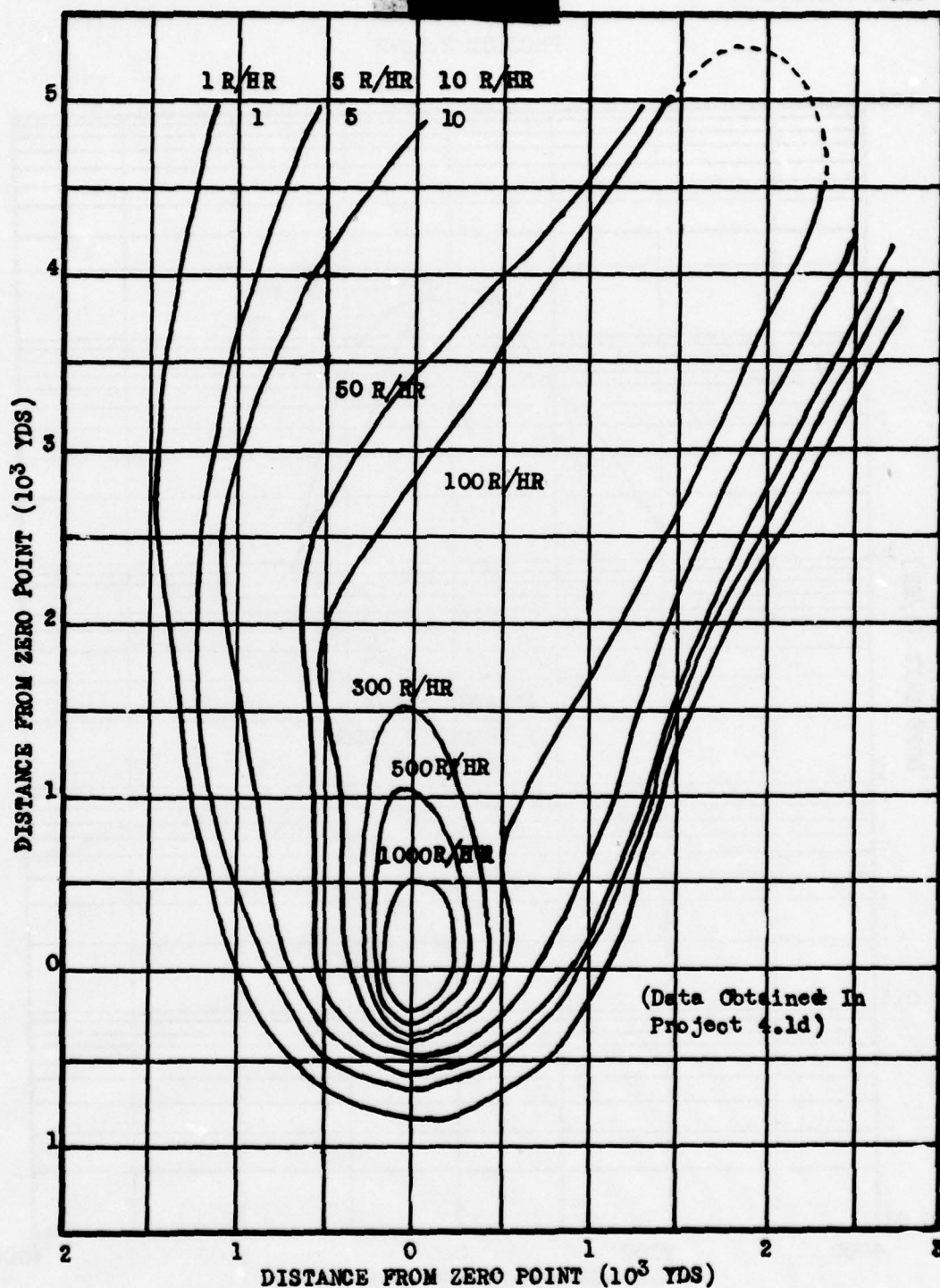
Fig. 4.4 Gamma Intensity Measured at Ground Level at H+1 Hour –
Underground Shot

- 37 -

OPERATION JANGLE

Project 2.1d

MONITOR SURVEY OF GROUND CONTAMINATION (RADSAFE)

by

G. W. Johnson, CDR, USN

22 May 1952

Armed Forces Special Weapons Project

MONITOR SURVEY OF GROUND CONTAMINATION (RADSAFE)

1.1   INTRODUCTION

Among the important effects to be expected from a surface or underground explosion is that of residual contamination on the ground. Quantitative information on the radiation intensities and the associated areas for such explosions was lacking prior to the JANGLE operation. It was the purpose of Project 2.1d to provide for the determination of the extent and magnitude of the radiation fields as measured by monitor survey teams using the Radiac Training Set AN/PDR-T1B for making the measurements.

1.2   PROCEDURE

All instruments were calibrated with gamma rays from an equilibrium radium source prior to each survey. In making readings the instrument in general was held about 3 feet above the ground, although very little difference was noted in varying the height from 2 to 4 feet, and every attempt was made to get a representative reading. Non-uniformities in the field were practically absent until the wind became sufficiently strong to shift the contamination, at which time there was a localization of contamination in ditches and behind obstructions.

The plan to get the necessary measurements involved, in addition to the RadSafe surveys, the taking of readings at stations of other projects, mainly those of Projects 2.1a and 2.1d.

The station layouts and the detailed data are given in Appendices A, B, and C.

1.3   RESULTS

The results were reduced to gamma dosage-rate contours at one hour after each explosion. In all cases the monitor survey information was collected at times later than one hour and therefore it was necessary to correct it to one hour. The correction for decay was based on the $t^{-1.2}$ decay law which was shown to be the best approximation from monitor surveys and from gamma decay of samples from the field. The radiation fields for the surface shot are shown in Fig. 1 and those for the underground in Fig. 2. The detailed data on which the curves were based are given in Appendices A, B, and C.

The values for the fields in the lip areas given in Figs. 1 and 2 were obtained by extrapolation to the lip areas of the fields obtained by surveys in the surrounding areas as given in Figs. 1 and 2. Surveys of the lips of both craters on 25 January 1952 corrected back to H-1 hour gave an average value for the surface shot of 6000 r/hr with a peak value of 8500 r/hr, which agrees well with the extrapolated average value of 7500 r/hr. For the underground shot, the survey of 25 January gave an average value of 6000 r/hr with a peak

-1-

PROJECT 2.1d

value of 7000 r/hr. The detailed values of the lip surveys of 25 January 1952 are given in Appendix C.

It must be emphasized that the particular distributions of con-tamination as found in Figs. 1 and 2 were a result of the particular wind conditions existing at the time of the detonation.

The wind pattern at the time of the surface shot (0900 PST, 19 November 1951) is given in Table 1.

TABLE 1

Wind Pattern at Time of Detonation - Surface Shot

Altitude above Surface Feet	Velocity Knots	Direction
0	2	190°
2000	13	170°
4000	26	180°
6000	32	200°
10,000	40	210°
12,000	44	210°
14,000	63	200°
16,000	54	200°

Following the surface detonation the wind pattern was unchanged for 12 hours. At that time the surface wind increased to 12 knots and continued to blow at 17 to 30 knots for about 24 hours. Accompanying the increase of wind at H-12 hours was a relatively heavy rainfall. The amount of precipitation was not measured by the weather observers at the site but it was sufficient to wet the desert surface to a depth of about 3/4 inch.

The effect of the rain was to stabilize the soil until about H-27 hours after which the soil had dried to such an extent that the wind was able to pick up dust again. For these reasons, the monitor survey data collected in the first 27 hours were considered to be more reliable than measurements made subsequently. Therefore, in drawing the contours the earlier measurements were given the greatest weight.

The wind pattern at the time of the underground shot (1200 PST, 29 November 1951) is given in Table 2.

PROJECT 2.1d

TABLE 2

Wind Pattern at Time of Detonation – Underground Shot

Altitude above Surface Feet	Velocity Knots	Direction -
0	calm	-
1000	3	100°
2000	8	190°
3000	12	210°
4000	17	210°
5000	22	220°
6000	21	220°
8000	25	240°

The surface winds remained less than 10 knots generally from the south for 48 hours following the shot, at which time the winds increased to about 20 knots. Since loose dust on the desert is moved about by winds of 15 to 20 knots, after 48 hours the distribution of radioactive material was modified by the winds. Therefore, in preparing the dose-rate contours, the measurements made prior to H-48 hours were given the greatest weight.

The assignment of the expected accuracy of the results is somewhat questionable but based on the overall performance of the survey instruments and the general consistency of the data, the radiation fields at a given point are probably accurate to ±25 percent. Such accuracy is certainly adequate because except for the large downwind areas of relatively low intensity, the field gradients are so steep that errors of 25 percent in radiation field do not markedly affect the _areas_ of contamination.

1.4 RECOMMENDATIONS

In future operations, in the event that another contaminating burst is fired, it is recommended that the station layouts for monitor survey follow the scheme that was used for the underground shot at JANGLE. The shape of the contaminated field following the surface shot was such that it lay between two arms of the radial arrangement of stations; and because of the narrowness and length of the contaminated areas, coverage of measurements was not as complete as desired. Because of this result, new stations for the underground shot in the downwind area were placed on arcs about the center of the explosion and therefore led to a more definite delineation of the field. Thus in future operations, if the need arises to determine the field contours, the stations should be so positioned that traverses are made at right angles to the expected direction of drift of the cloud at appropriate downwind positions. The upwind and crosswind contours are best determined by a radial arrangement of stations.

-3-
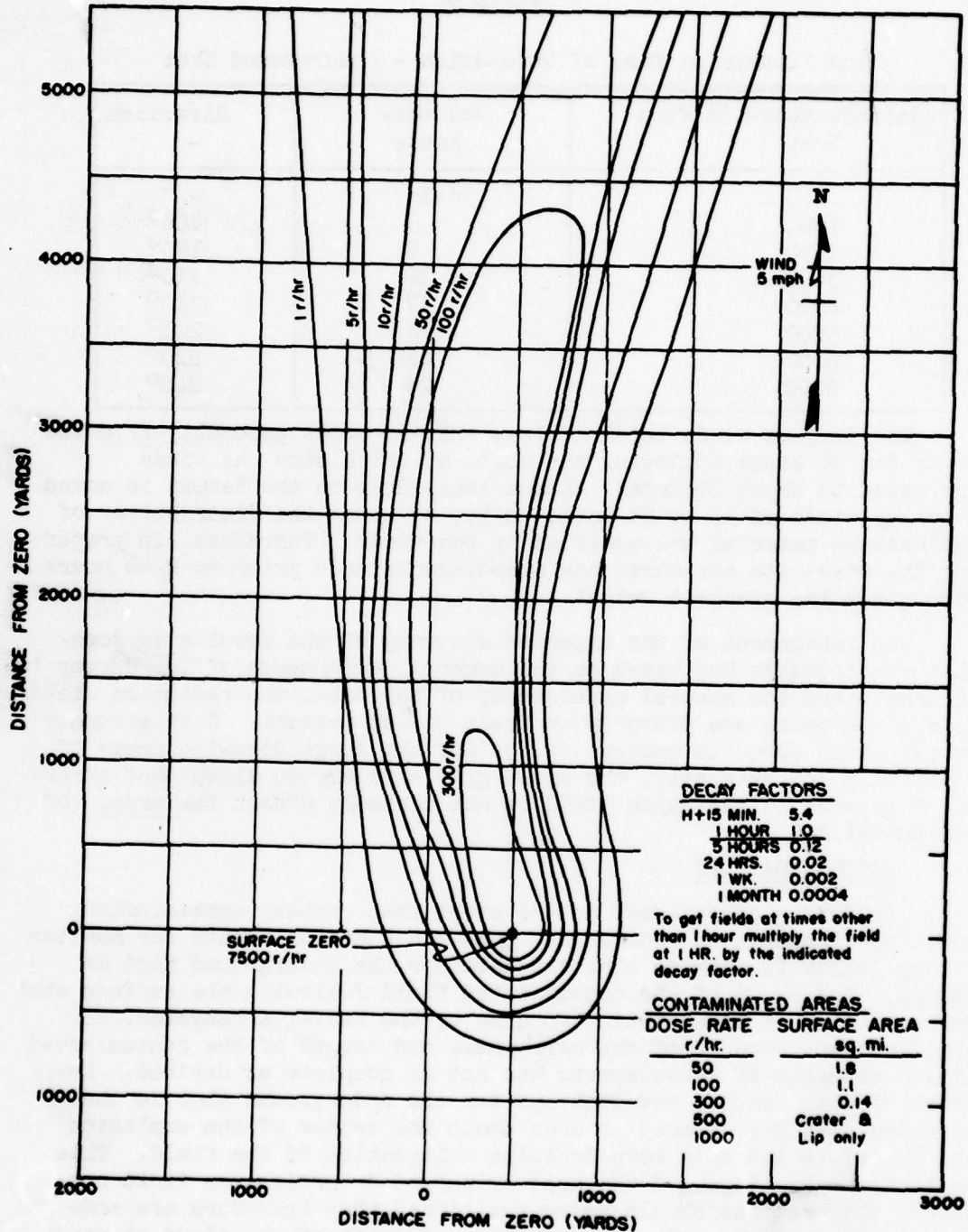
PROJECT 2.1d

Fig. 1 Gamma Dose-Rate Contours at H∔1 hour - Surface Burst

PROJECT 2.1d

DECAY FACTORS

H+15 MIN.	5.4
I HOUR	1.0
5 HOURS	0.12
24 HRS.	0.02
I WK.	0.002
I MONTH	0.0004

To get fields at times other than I hour multiply the field at I HR. by the indicated decay factor.

CONTAMINATED AREAS

DOSE RATE r/hr.	SURFACE AREA sq. mi.
50	Large
100	2.1
300	0.34
500	0.2
1000	0.08
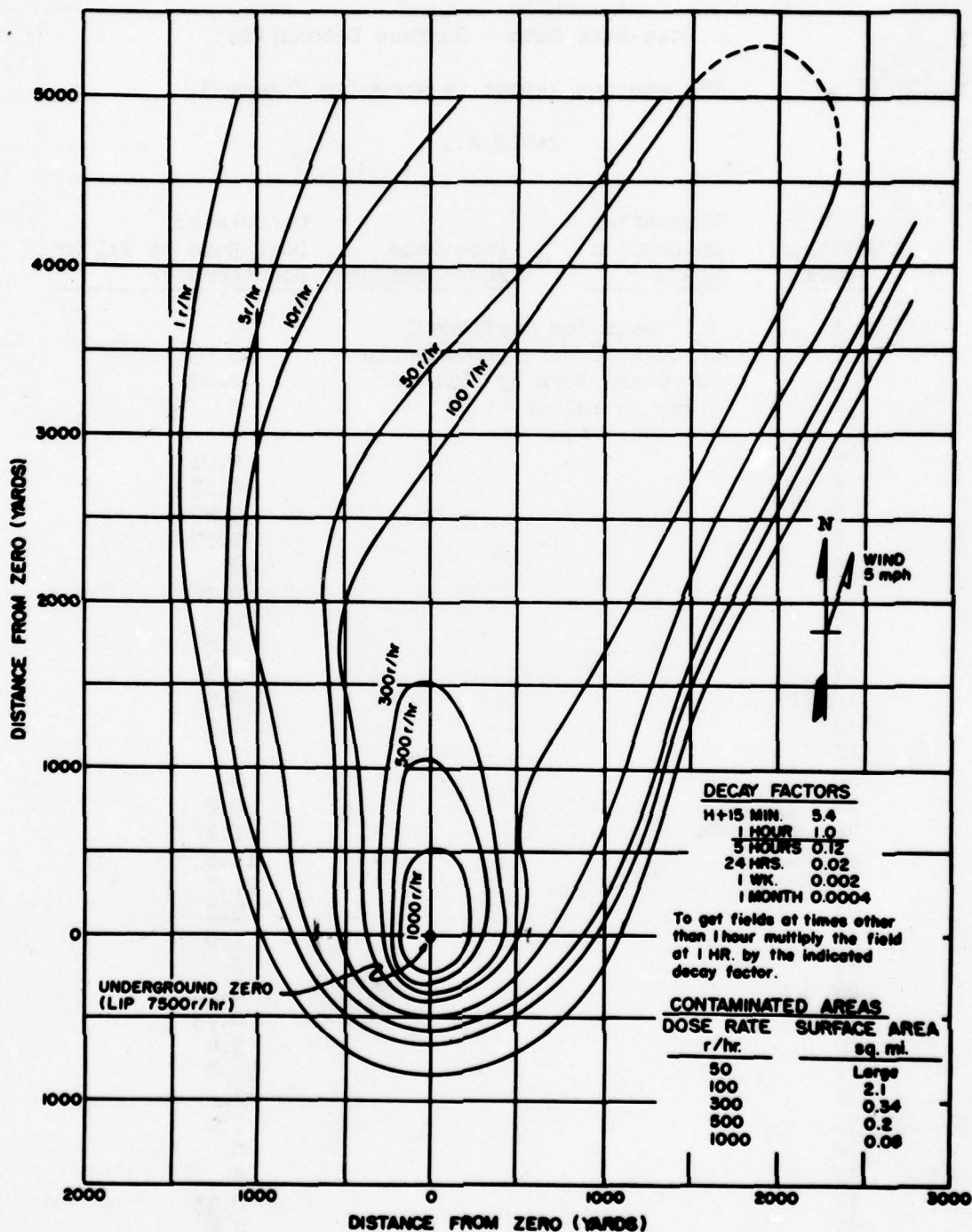
Fig. 2 Gamma Dose-Rate Contours at H+1 hour – Underground Burst

PROJECT 2.1d

APPENDIX A

Dose-Rate Data - Surface Detonation

The station layout is shown in Figure 3

TABLE A.1

Station Number	Time after Detonation Hours	Dose-Rate Roentgens/hr	Calculated Dose-Rate at H+1 hr Roentgens/hr
1	Data for stations 1		0
2	through 68 were provided in		0.03
3	corrected form by NRDL as		0.03
4	given in column 4.		0
5			0
6			0.05
7			0.17
8			0.25
9			0.17
10			0
11			0.06
12			0.3
13			1.0
14			1.1
15			0.5
16			0.3
17			0
18			0
19			0.2
20			1.1
21			11.0
22			27.5
23			8.2
24			1.0
25			0
26			0.06
27			0.33
28			3.4
29			81.0
30			42.0
31			1.0
32			0
33			0
34			0.33
35			2.6
36			208.0

PROJECT 2.1d

TABLE A.1 (cont'd)

Station Number	Time after Detonation Hours	Dose-Rate Roentgens/hr	Calculated Dose-Rate at H+1 hr Roentgens/hr
37			540.0
38			11.0
39			0.5
40			0
41			0.12
42			0.33
43			16.5
44			480.0
45			208.0
46			3.4
47			0.10
48			0
49			0.12
50			0.58
51			71.0
52			350.0
53			170.0
54			1.4
55			0.06
56			0
57			0.12
58			1.4
59			93.0
60			350.0
61			91.5
62			0.94
63			0.01
64			0
65			69.0
66			115.0
67			115.0
68			115.0
69	5.5	0	0
	22	0	0
	50	0	0
70	6.	0.06	0.52
	22	0.018	0.74
	50	0.005	0.50
71	4.9	0.003	0.022

PROJECT 2.1d

TABLE A.1 (con't)

Station Number	Time after Detonation Hours	Dose-Rate Roentgens/hr	Calculated Dose-Rate at H+1 hr Roentgens/hr
72	4.9	0.22	1.48
	22.	0.032	1.31
	50.	0.008	0.88
73	5.4	0.080	0.60
	22	0.022	0.90
	50	0.008	0.83
74	5.4	0.010	0.76
	22	0.005	0.21
75	5.6	0.160	1.27
	22	0.034	1.39
	50	0.013	1.40
76	5.6	0.020	0.16
	22	0.005	0.21
77	5.5	2.40	18.5
	22	0.36	14.8
	50	0.165	18.1
	72	0.05	8.5
78	5.4	1.05	7.9
	22	0.080	3.3
	50	0.038	4.2
	72	0.012	2.0
79	50	0.31	34.
	72	0.20	34.
80	5.4	0.90	6.8
	22	0.033	1.4
	50	0.018	2.0
	72	0.008	1.4
81	50	0.017	1.0
	72	0.010	3.3
82	5.4	0.75	5.7
	22	0.012	1.0
	50	0.009	0.5

PROJECT 2.1d

TABLE A.1 (cont'd)

Station Number	Time after Detonation Hours	Dose-Rate Roentgens/hr	Calculated Dose-Rate at H+1 hr Roentgens/hr
83	50	0.0004	0.04
84	5.3	0.65	4.8
	50	0.007	.8
	72	0.002	.3
85	5.3	1.25	9.3
	22	0.12	4.9
	50	0.041	4.5
	72	0.026	4.4
86	96	0	0
87	96	0.03	7.2
88	22	1.0	41.
	72	0.20	34.
	96	0.10	24.
89	22	0.90	37.
	72	0.14	24.
	96	0.08	19.
90	5.2	0.81	5.8
	22	0.120	4.9
	50	0.055	6.0
	72	0.019	3.2
	96	0.010	2.4
91	72	0	0
92	72	0.036	6.1
	96	0.022	5.3
93	72	0.090	15.0
	96	0.050	12.0
94	72	0.180	31.0
	96	0.100	24.0
95	72	0.018	3.1
	96	0.010	2.4

-9-

PROJECT 2.1d

TABLE A.1 (con't)

Station Number	Time after Detonation Hours	Dose-Rate Roentgens/hr	Calculated Dose-Rate at H+1 hr Roentgens/hr
96	72	0.120	20.0
	96	0.060	15.0
97	72	0.270	46.0
	96	0.110	26.0
98	72	0.008	1.4
99	72	0.090	15.0
	96	0.040	10.0
100	72	0.230	39.0
	96	0.100	24.0
101	72	0.038	6.5
	96	0.030	7.2
102	72	0.250	42.0
	96	0.120	29.0
103	6.0	2.10	18.0
	72	0.180	31.0
	96	0.090	23.0
104	72	0.026	4.4
	96	0.009	2.3

PROJECT 2.1d
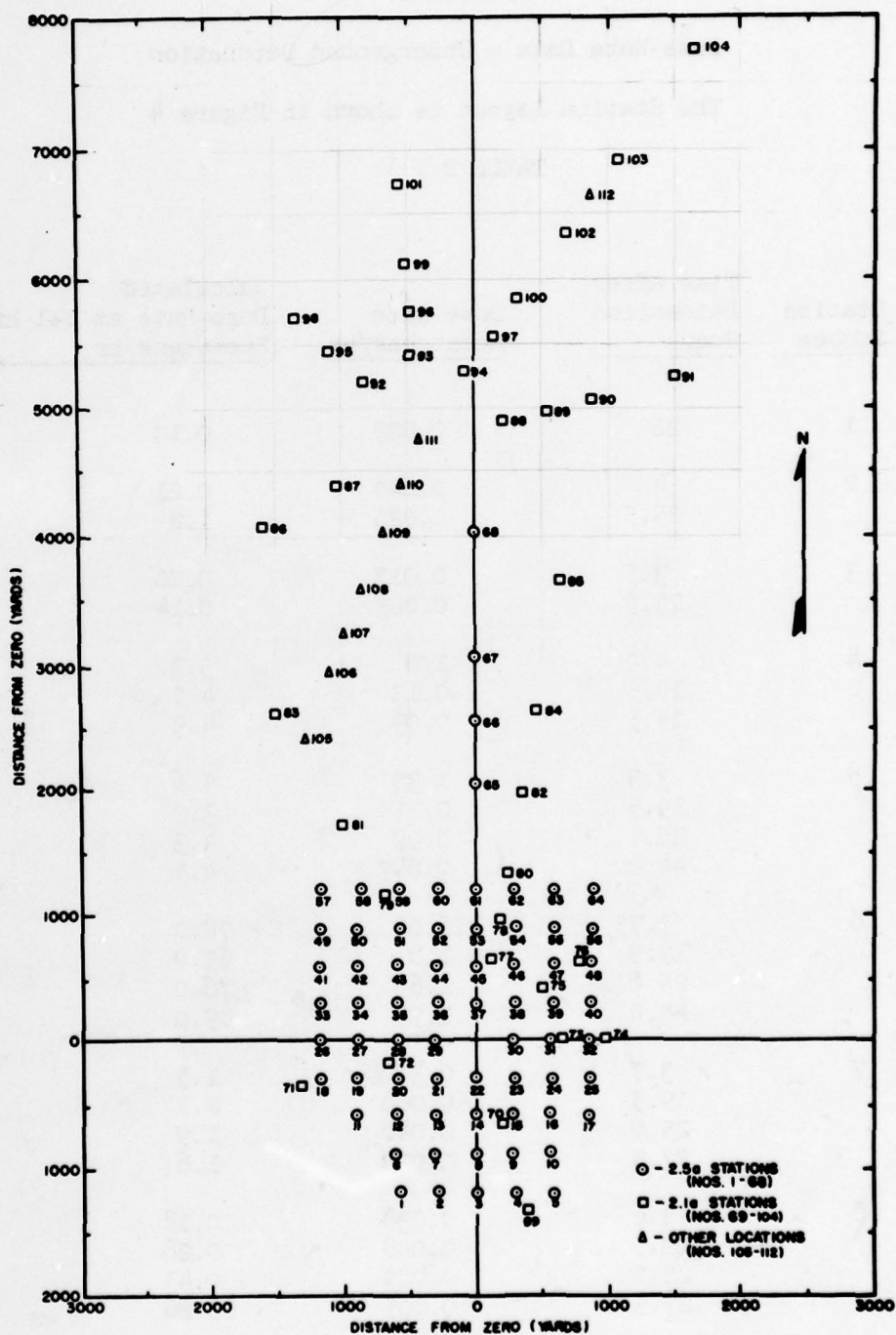

Fig. 3 Station Layout - Surface Shot

-11-

PROJECT 2.1d

APPENDIX B

Dose-Rate Data - Underground Detonation

The Station layout is shown in Figure 4

TABLE B.1

Station Number	Time after Detonation Hours	Dose-Rate Roentgens/hr	Calculated Dose-Rate at H+1 hr Roentgens/hr
1	26	0.002	0.10
2	4	0.040	0.21
	25.5	0.025	1.2
3	3.5	0.013	0.06
	25.5	0.003	0.14
4	4.0	1.0	5.3
	19.5	0.13	4.5
	25.5	0.09	4.3
5	3.5	1.30	5.6
	19.5	0.11	3.9
	25.5	0.09	4.3
	44.0	0.047	4.4
6	3.75	16.0	78.0
	19.5	1.8	63.0
	25.0	1.6	76.0
	44.0	0.95	89.0
7	3.7	0.30	1.5
	19.5	0.060	2.1
	25.0	0.040	1.9
	27.5	0.030	1.6
8	3.7	0.038	0.18
	19.5	0.008	0.28
	25.0	0.009	0.43
	27.5	0.005	0.26
9	25.0	0.002	0.09

PROJECT 2.1d

TABLE B.1 (con't)

Station Number	Time after Detonation Hours	Dose-Rate Roentgens/hr	Calculated Dose Rate at H+1 hr Roentgens/hr
10	19.5	2.50	87.0
	26.5	1.40	70.0
	44.0	0.95	89.0
11	24.5	10.0	460.0
12	24	6.0	270.0
13	19.5	0.38	13.3
	26.5	0.20	10.0
	44.0	0.15	14.0
14	24.5	9.0	415.0
15	24.0	0.7	31.5
16	19.5	0.26	9.1
	26.0	0.11	5.5
	44.0	0.10	9.3
17	24.5	7.0	320.0
	27.5	4.8	250.0
18	24.0	0.170	7.6
19	19.5	0.034	1.2
	26.0	0.012	0.6
20	24.5	3.6	166.0
	27.5	3.3	174.0
21	24.0	1.2	54.0
	27.5	1.0	53.0
22	26.0	0.009	0.5
23	24.5	1.7	78.0
	27.5	1.2	63.0
24	25.0	0.28	13.0
25	24.5	0.50	23.0
	27.5	0.40	21.0

PROJECT 2.1d

TABLE B.1 (con't)

Station Number	Time after Detonation Hours	Dose-Rate Roentgens/hr	Calculated Dose-Rate at H+1 hr Roentgens/hr
26	24.0	0.38	17.0
	27.5	0.30	16.0
27	24.5	0.16	7.4
	27.5	0.14	7.4
28	27.0	0.20	9.5
29	1.5	.01	.016
30	1.5	0.24	0.39
31	1.5	1.1	1.8
32	1.5	2.5	4.1
	19.5	0.10	3.5
	44.0	0.10	9.4
33	1.5	4.0	6.5
34	1.5	17.0	28.0
	19.5	0.50	18.0
	27.5	0.32	17.0
	44.0	0.22	21.0
35	19.5	4.0	140.0
	44.0	2.1	200.0
36	70.0	1.5	250.0
37	70.0	3.6	590.0
38	70.0	9.0	1480.0
39	2.0	0.008	0.018
	1.5	0.01	0.016
40	2.0	0.080	0.18
	1.5	0.050	0.08
41	2.0	0.170	0.39
	1.5	0.22	0.36

PROJECT 2.1d

TABLE B.1 (con't)

Station Number	Time after Detonation Hours	Dose-Rate Roentgens/hr	Calculated Dose-Rate at H+1 hr Roentgens/hr
42	2.0	0.70	1.60
	1.5	0.48	0.78
43	2.0	3.8	8.7
44	2.0	20	46.0
	1.5	22	36.0
45	1.5	50	81.0
46	19	0.11	3.8
47	19	0.22	7.7
	27.5	0.10	5.3
	44	0.10	9.4
48	19	0.30	10.5
	27.5	0.14	7.4
	44	0.15	14.0
49	19	0.48	16.8
	27.5	0.30	15.9
	44	0.30	28.2
50	19	1.00	35.0
	27.5	0.50	27.0
	44	0.90	85.0
51	19	4.6	161
	27.5	3.6	191
	44	3.0	282
52	19	5.5	192
53	19	6.0	210
	27.5	3.5	186
54	19	4.2	147
	27.5	3.2	170
	44	2.8	263

PROJECT 2.1d

TABLE B.1 (con't)

Station Number	Time after Detonation Hours	Dose-Rate Roentgens/hr	Calculated Dose-Rate at H+1 hr Roentgens/hr
55	19	5.5	192
	27.5	4.4	233
	44	3.1	292
56	19	5.2	182
	27.5	3.9	207
	44	3.5	329
57	19	4.2	147
	27.5	4.8	254
	44	2.8	263
58	19	2.6	91
	27.5	1.6	85
	44	1.5	141
59	19	2.0	70
	27.5	1.9	101
	44	1.4	132
60	19	1.8	63
	27.5	1.6	85
	44	1.4	132
61	19	1.3	46
	44	1.2	113
62	2.5	6.0	18
	19	0.5	18
	44	0.6	56
63	19	0.018	0.63
	44	0.015	1.4
64	2.5	0.060	0.18
	19	0.006	0.21
	44	0.009	0.85
65	19	0.004	0.14
66	19	Background	-
67	19	Background	-
68	27.5	3.3	175

-16-

TABLE B.1 (con't)

Station Number	Time after Detonation Hours	Dose-Rate Roentgens/hr	Calculated Dose-Rate at H+1 hr Roentgens/hr
69	27.5	1.4	72
70	27.5	1.2	62
71	27.5	0.44	23.
72	27.5	0.28	15
73	27.5	0.20	11
74	27.5	0.30	16
75	27.5	0.16	8.5
76	24	0.60	27
	27.5	0.60	32
77	27.5	0.60	32
78	24	1.10	50
	27.5	0.80	42
79	27.5	2.8	148
80	24	3.2	144
	27.5	3.1	164
81	24	2.8	126
	27.5	2.8	148
82	27.5	1.6	85
83	27.5	0.26	14
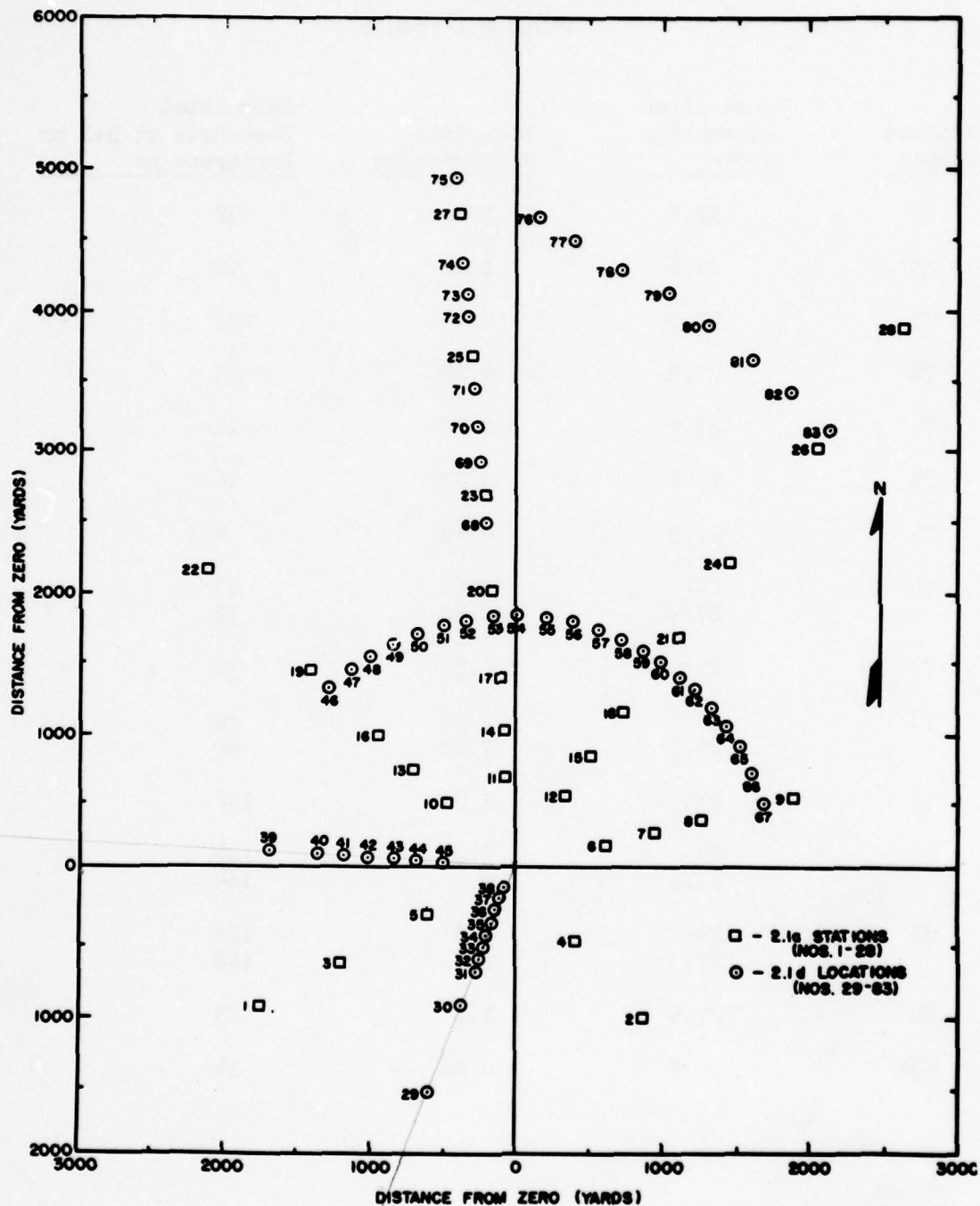
PROJECT 2.1d

Fig. 4 Station Layout - Underground Shot

-18-

UNCLASSIFIED

APPENDIX C

Surveys of Lips

On 25 January 1952 monitor surveys were made of the lip areas of the underground and surface shots. Readings were made at eight positions equally spaced on a circle surrounding the craters and are listed below.

TABLE C.1

Station Number	Surface Shot Rate Roentgens/hr	Rate Corrected to H+1 hr Roentgens/hr
1	1.2	8600
2	1.1	7900
3	1.0	7200
4	0.90	6500
5	0.32	2300
6	0.50	3600
7	0.60	4300
8	1.0	7200

Mean......6000 r/hr

Station Number	Underground Shot Rate Roentgens/hr	Rate Corrected to H+1 hr Roentgens/hr
1	1.2	7000
2	1.0	5800
3	0.95	5500
4	0.90	5200
5	1.0	5800
6	1.0	5800
7	1.05	6100
8	1.10	6400

Mean......6000 r/hr

UNCLASSIFIED

OPERATION JANGLE

Project 2.3-1

TOTAL DOSAGE

by

LT. COL. MERWIN B. FORBES
MR. ROSS G. LARRICK
CPL. EDWARD J. FULLER

March 15, 1952

SIGNAL CORPS ENGINEERING LABORATORIES

FORT MONMOUTH, NEW JERSEY
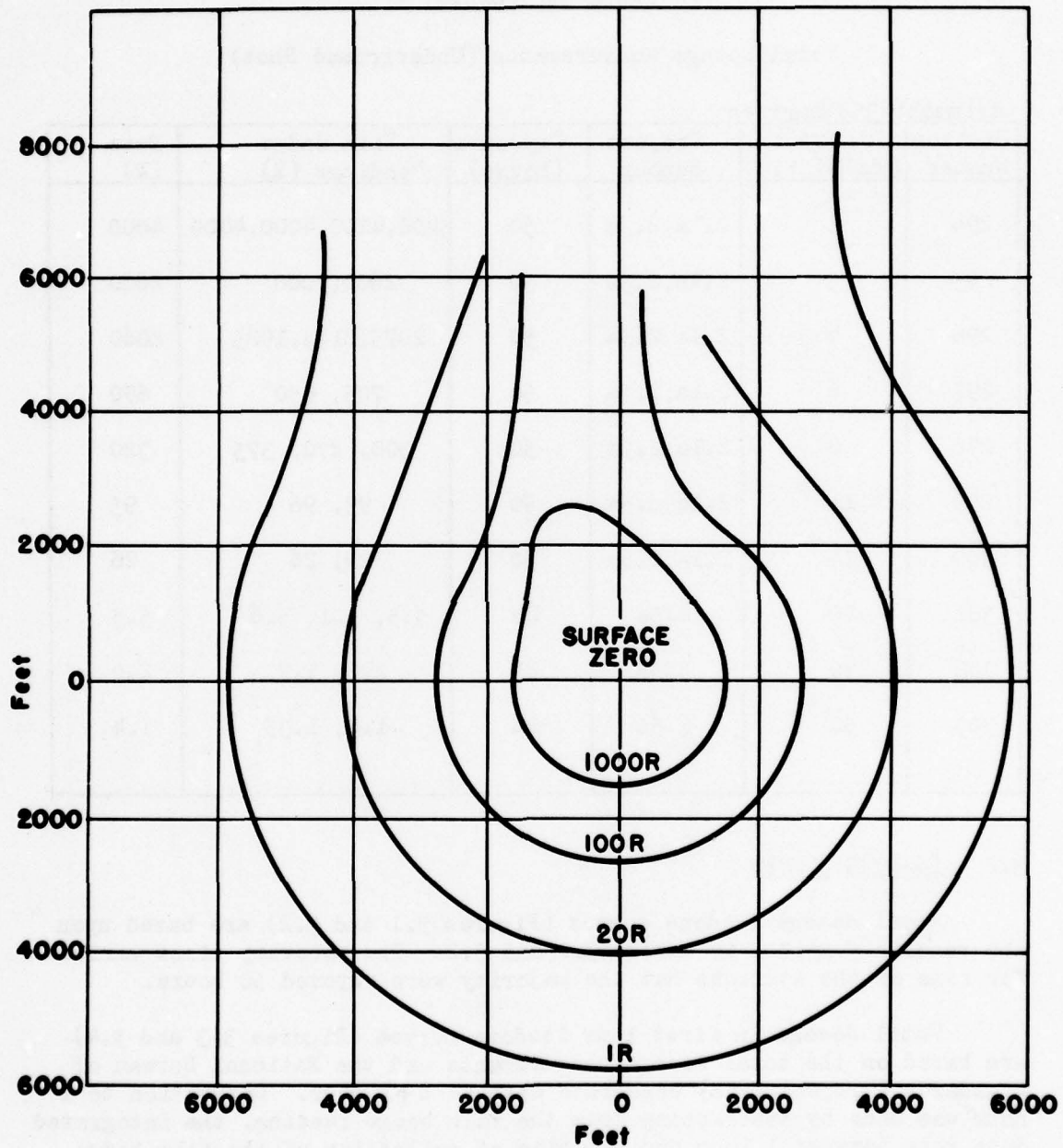
PROJECT 2.3-1
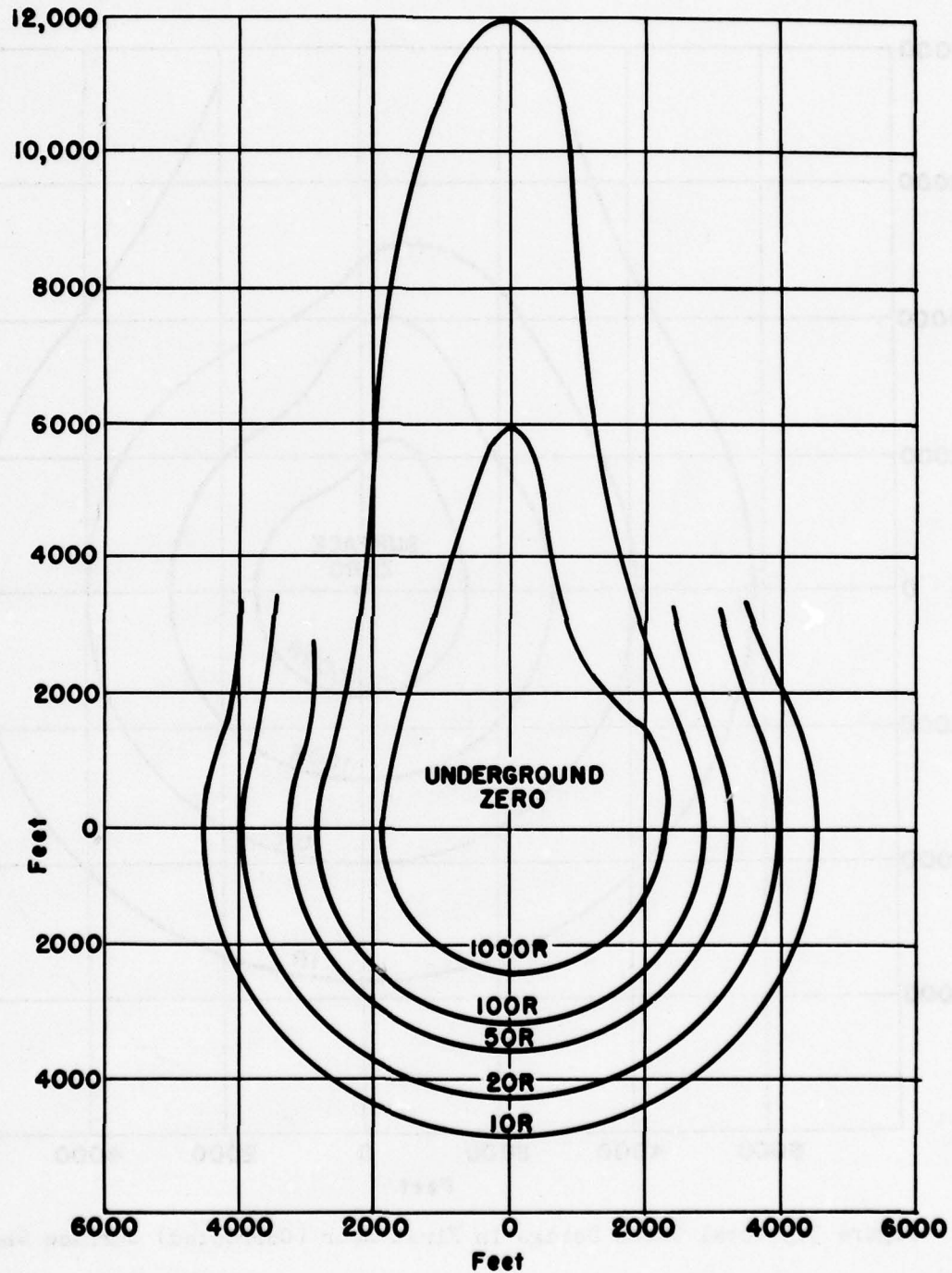

Figure 3.1 Total Gamma Dosage (50 Hours) Surface Shot

PROJECT 2.3-1

Figure 3.2 Total Gamma Dosage (50 Hours) Underground Shot

- 27 -
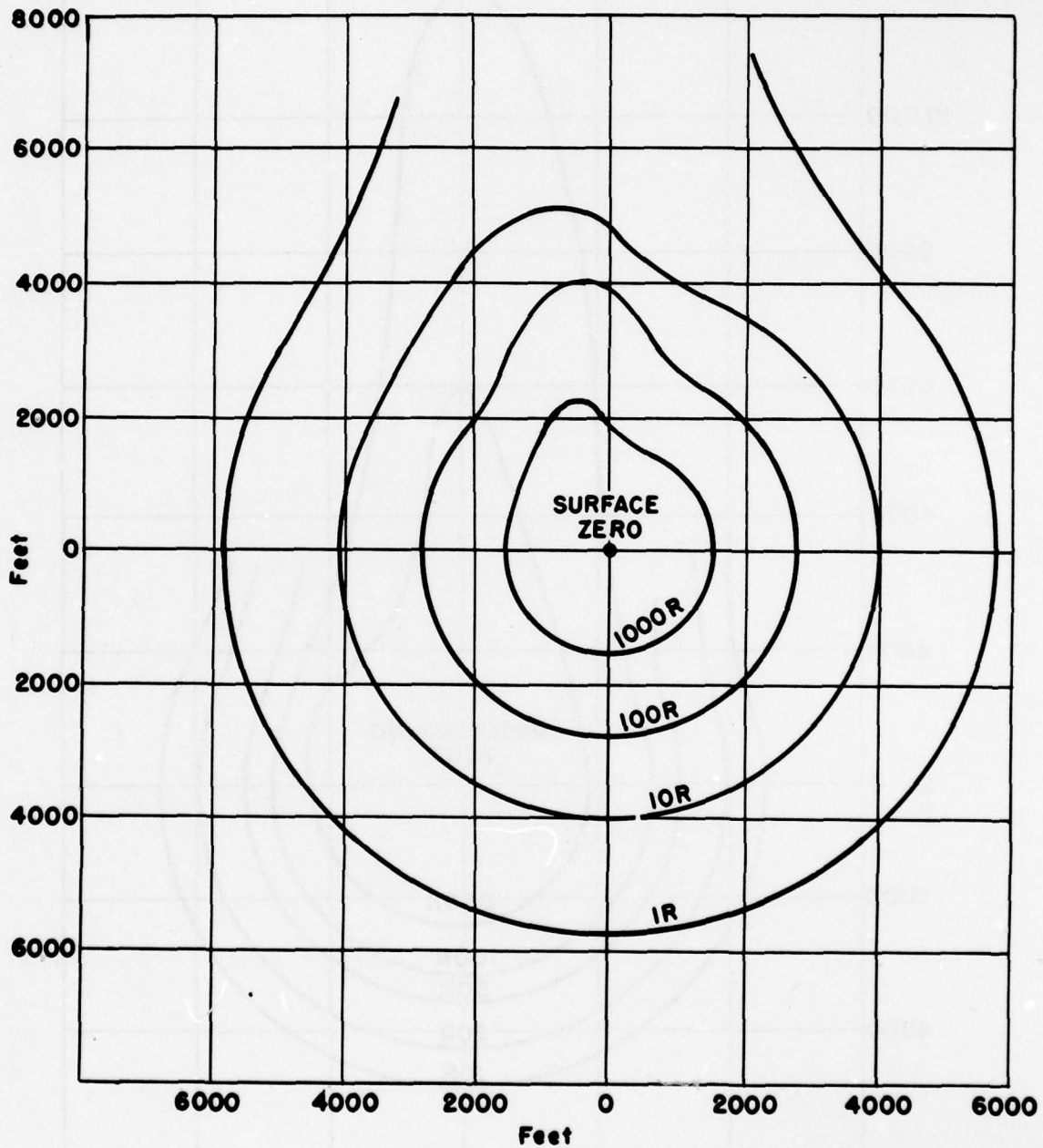
PROJECT 2.3-1

Figure 3.3 Total Gamma Dosage in First Hour (Corrected) Surface Shot
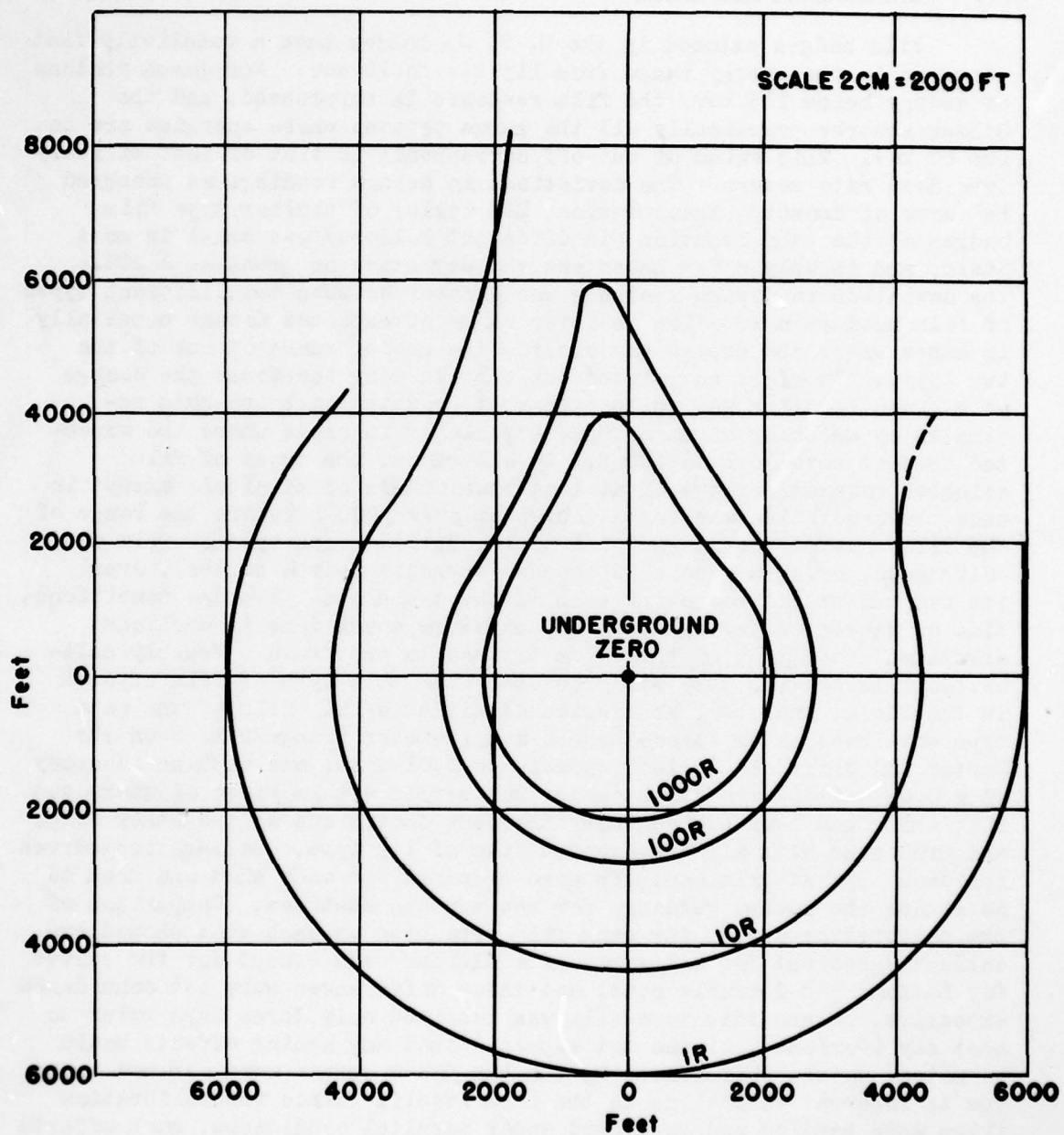
PROJECT 2.3-1

Figure 3.4 Total Gamma Dosage in First Hour (Corrected) Underground Shot

OPERATION JANGLE
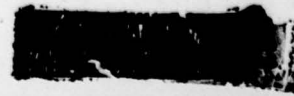
PROJECT 2.3-2

FOXHOLE SHIELDING OF GAMMA RADIATION

by

THOMAS G. WALSH

27 June 1952

ENGINEER RESEARCH AND DEVELOPMENT LABORATORIES

PROJECT 2.3-2

ABSTRACT

This project was designed by the Corps of Engineers to evaluate the protection afforded by foxholes against the gamma radiation emitted by atomic weapons detonated on the surface and beneath the ground. Film dosimeters were used to measure total gamma ray doses at different depths in one and two-man foxholes as well as in soil pipes sunk into the ground. The film dosimeters were contained in National Bureau of Standards' type holders and responded to gamma radiation of energy greater than 120 Kev. In the report, all doses are given in terms of roentgens and a reading of 650r (roentgens) is taken as the lethal dose; that is, the dose which will cause death to nearly 100 per cent of exposed personnel.

The major conclusions of this experiment, based on the data obtained in the above manner, follow:

1. Standard foxholes, as described in FM 5-15, provide excellent protection to personnel from the gamma radiation emitted during the detonation of an atomic weapon on the surface of the ground. The results show that the doses in the bottom of such foxholes located in the crosswind direction during Operation JANGLE were less than 10 per cent of the surface doses at identical locations. Since the foxholes were located outside of the major fall-out pattern, the complete dose measured was due to scattered prompt radiation. If the foxholes had been located downwind, however, the doses would have been higher, since fall-out into the foxhole and scattered radiation from the contamination on the surface would contribute more significantly to the total dose. There are indications that these contributions will not materially change the per cent of surface-received radiation reaching trained personnel in the bottom of the foxholes. An increase of surface contamination will increase the surface dose as well as the dose at the bottom of the foxhole, thereby maintaining the ratio between the two. The contaminated matter that falls into the foxhole can easily be removed by occupying personnel before it has time to increase the doses received to any great extent.

2. Except in those areas covered by extensive fall-out, foxholes also provided effective shielding in the case of the underground detonation of Operation JANGLE. The doses at the bottom of the foxholes varied from about 24 to 38 per cent of the surface doses at distances greater than 2500 feet from the burst. A great portion of this

dose, about 90 per cent, was obviously due to radioactive matter that fell into the foxhole, because the doses measured in the holes during the surface shot were approximately 10 per cent of those measured during the underground shot of identical yield. It is expected that both bursts contributed equally to the doses as far as prompt radiation is concerned.

3. The doses obtained from the detonation of atomic weapons on the surface or underground receive contributions from prompt gamma radiation, radiation emanating from column and cloud, and from residual activity due to fall-out of radioactive matter. No base surge activity was evident.

4. The complete doses at the bottom of the foxholes after the surface burst of this operation were attributable to scattered prompt radiation in addition to a small contribution from the column and cloud; no material contribution from fall-out or residual activity was evident. This lack of effect undoubtedly resulted from the location of the foxholes in the crosswind direction. If the foxholes had been located downwind, there would have been a material contribution from fall-out and residual activity. It is not expected that this would falsify the conclusions drawn in this report on the effectiveness of foxholes as protection for personnel against gamma radiation. (See conclusion 1, above.)

5. The major portion of the total dose measured at the bottom of the foxholes after the underground burst apparently came from fall-out matter in the foxhole. Contamination on the surface of the ground surrounding the foxhole contributed only about 10 per cent to the doses at the bottom of these structures, and prompt radiation could not contribute more than evidenced in the surface burst since both weapons were the same size. Yet, in all cases the doses were considerably higher during the underground detonation, leading to the obvious conclusion that matter falling into the foxholes played the most important role. Also, the doses in the two and one-man foxholes were equal, although the two man foxhole had twice the opening area. If the column or cloud activity contributed greatly to these doses, it could be expected that the doses in the two-man foxhole would be about twice as great as those in the one-man structure.
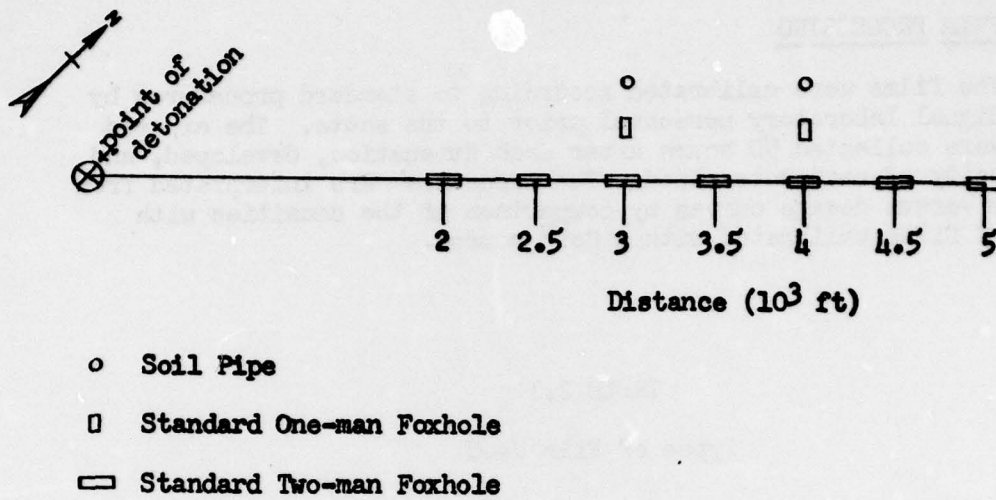
PROJECT 2.3-2

Distance (10^3 ft)

o   Soil Pipe

□   Standard One-man Foxhole

▭   Standard Two-man Foxhole

Fig. 2.1 Location of Foxholes
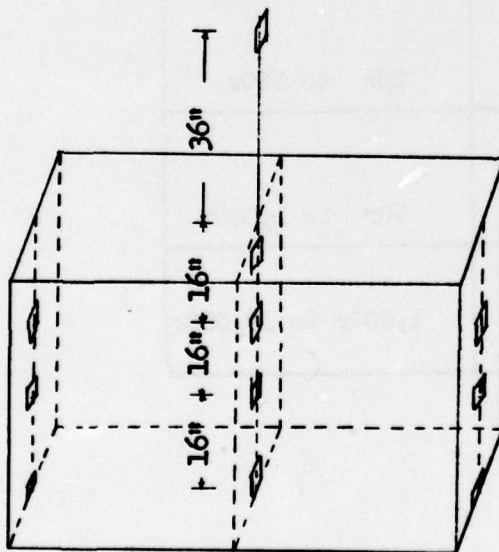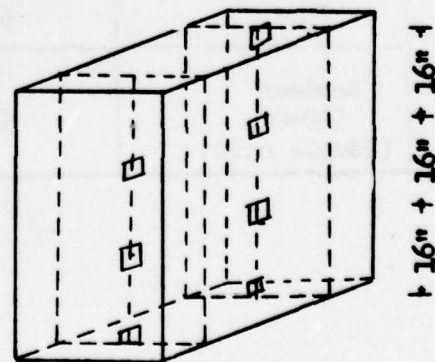

Fig. 2.2 Film Locations in
Two-man Foxholes

Fig. 2.3 Film Locations in
One-man Foxholes

- 3 -

CHAPTER 3

TEST RESULTS

3.1   GAMMA RADIATION RESULTS

The integrated gamma doses in roentgens measured in foxholes at various distances from the detonations are shown in Tables 3.1 and 3.2 for the surface and underground bursts respectively. These doses are given for five different levels in a two-man foxhole, 3 feet above the surface of the ground, at the surface, and 16, 32, and 48 inches below the surface. At each level below the surface, three doses are given in the two-man foxholes and two doses in the one-man foxhole, representing the results of films located in the positions shown in Fig. 2.2.

Figs. 3.1 through 3.6 are reproductions of the results obtained in Project 2.1A, Operation JANGLE. They depict the dose rates at one hour after the bursts, the total dose received in the first ten minutes and in one hour for both the surface and underground shots. The presentation of these graphs is necessary in this report since the film badges were not collected until fifty hours after the bursts and the graphs give an estimate of the contribution that residual radiation made to the total doses. On these graphs the locations of the foxholes have been superimposed to facilitate the evaluation of the results. Fig. 3.7 shows the prompt radiation expected from detonations of weapons of the size employed in the tests. The curves show the logarithm of the dose received as a function of the distance from the point of detonation to the films. Fig. 3.8 shows the theoretical value of the integrated dose at any time after the burst assuming a dose rate of 1 r per hour at 1 hour after the detonation and a decay law of $t^{-1.2}$. Total doses for any other dose rate may be obtained by multiplying the values on the graph by the desired rate at H+1 hours.

PROJECT 2.3-2
TABLE 3.1

Distribution of Gamma Radiation in Foxholes (Surface Burst)

Range (ft)	Location	Two-man Foxhole			One-man Foxhole		Soil Pipe
2000	36" Above Surface		800 r				
	Surface		700				
	16" Below Surface	230	205	415			
	32" Below Surface	24	58	136			
	48" Below Surface	12.8	22	62			
2500	36" Above Surface		230 r				
	Surface		220				
	16" Below Surface	35	60	85			
	32" Below Surface	7	15	26			
	48" Below Surface	4	8.5	13.3			
3000	36" Above Surface		110 r				73 r
	Surface		90			55	
	16" Below Surface	23	36	55	6.8	6.6	10
	32" Below Surface	7.6	12.4	19.4	2.5	2.4	0.5
	48" Below Surface	2.5	4.8	6.7	1.6	1	0
3500	36" Above Surface		41 r				
	Surface		---				
	16" Below Surface	3	---	9.7			
	32" Below Surface	1.6	2.8	3.4			
	48" Below Surface	.54	.99	1.9			
4000	36" Above Surface		17 r				17 r
	Surface		9.6			--	
	16" Below Surface	1.6	3	5.6	--	0.35	--
	32" Below Surface	0.6	1.12	1.62	--	--	0.17
	48" Below Surface	--	0.54	0.57	0.39	--	--
4500	36" Above Surface		9.8 r				
	Surface		4.6				
	16" Below Surface	1	1.8	3.5			
	32" Below Surface	0.5	0.7	1.04			
	48" Below Surface	0.21	0.4	0.57			
5000	36" Above Surface		4.8 r				
	Surface		2.7				
	16" Below Surface	0.6	0.99	2.95			
	32" Below Surface	0.3	0.5	0.75			
	48" Below Surface	0.17	0.2	0.38			

PROJECT 2.3-2

TABLE 3.2

Distribution of Gamma Radiation in Foxholes (Underground Burst)

Range (ft)	Location	Two-man Foxhole			One-man Foxhole		Soil Pipe
2000	36" Above Surface	3850 r					
	Surface		2300				
	16" Below Surface	1150	--	800			
	32" Below Surface	700	1000	555			
	48" Below Surface	200	200	200			
2500	36" Above Surface	1000 -- 550 r					
	Surface		78				
	16" Below Surface	78	98	115			
	32" Below Surface	43	56	50			
	48" Below Surface	73.4	94	96			
3000	36" Above Surface	175 r					155 r
	Surface		103			75	
	16" Below Surface	30	42	37	20	--	7
	32" Below Surface	22	23	20	15	11	3
	48" Below Surface	43.5	45	54	41	38	3
3500	36" Above Surface	--					
	Surface		48				
	16" Below Surface	12	17	15			
	32" Below Surface	9	10	9			
	48" Below Surface	15	15	22			
4000	36" Above Surface	32 r					28 r
	Surface		22			14	
	16" Below Surface	6	7	15	7	4	2
	32" Below Surface	5	3.4	7.2	3.7	2.8	0
	48" Below Surface	6	8.4	8.6	5	9.8	1.1
4500	36" Above Surface	22 r					
	Surface		10				
	16" Below Surface	4	5	5			
	32" Below Surface	5.8	2.8	2.8			
	48" Below Surface	--	7.7	8.9			
5000	36" Above Surface	73 r					
	Surface		23				
	16" Below Surface	15	15	67			
	32" Below Surface	21.5	22.6	15			
	48" Below Surface	--	21	19			

PROJECT 2.3-2

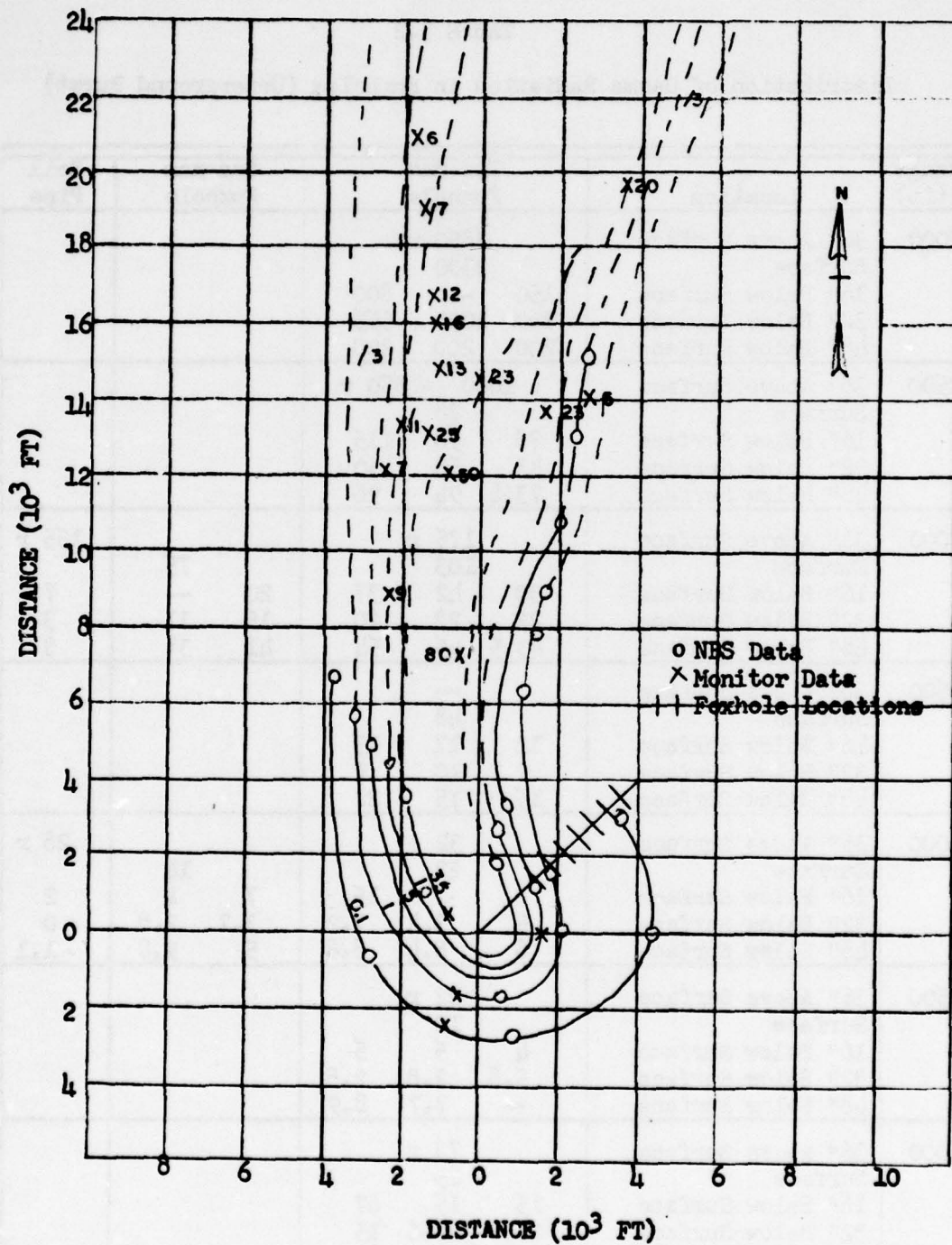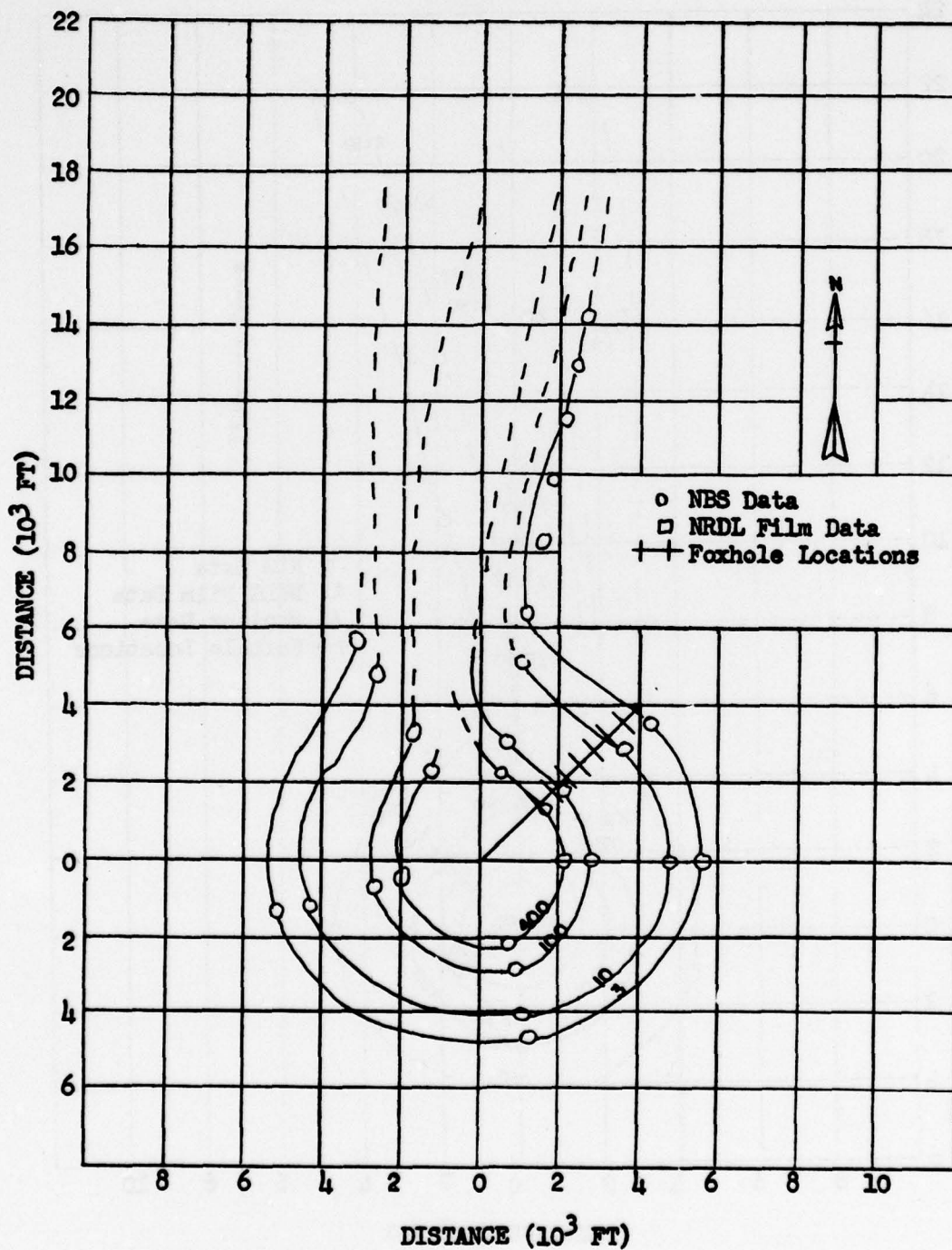
Fig. 3.1 Surface Burst, Iso-Rate Contours At 1 Hr.

- 8 -

PROJECT 2.3-2

Fig. 3.2 Surface Burst, Iso-Dose Contours at 10 Minutes

- 9 -

PROJECT 2.3-2
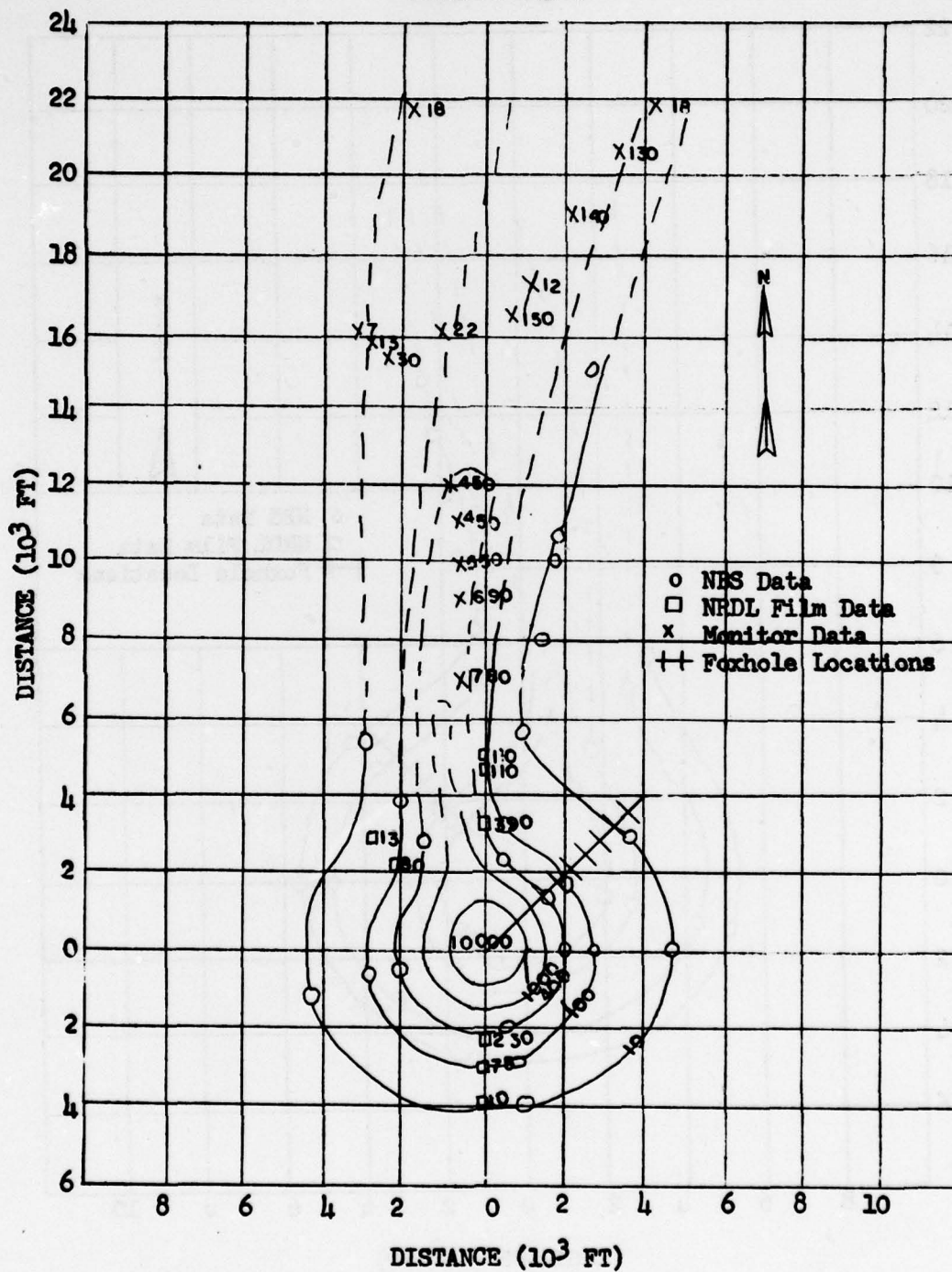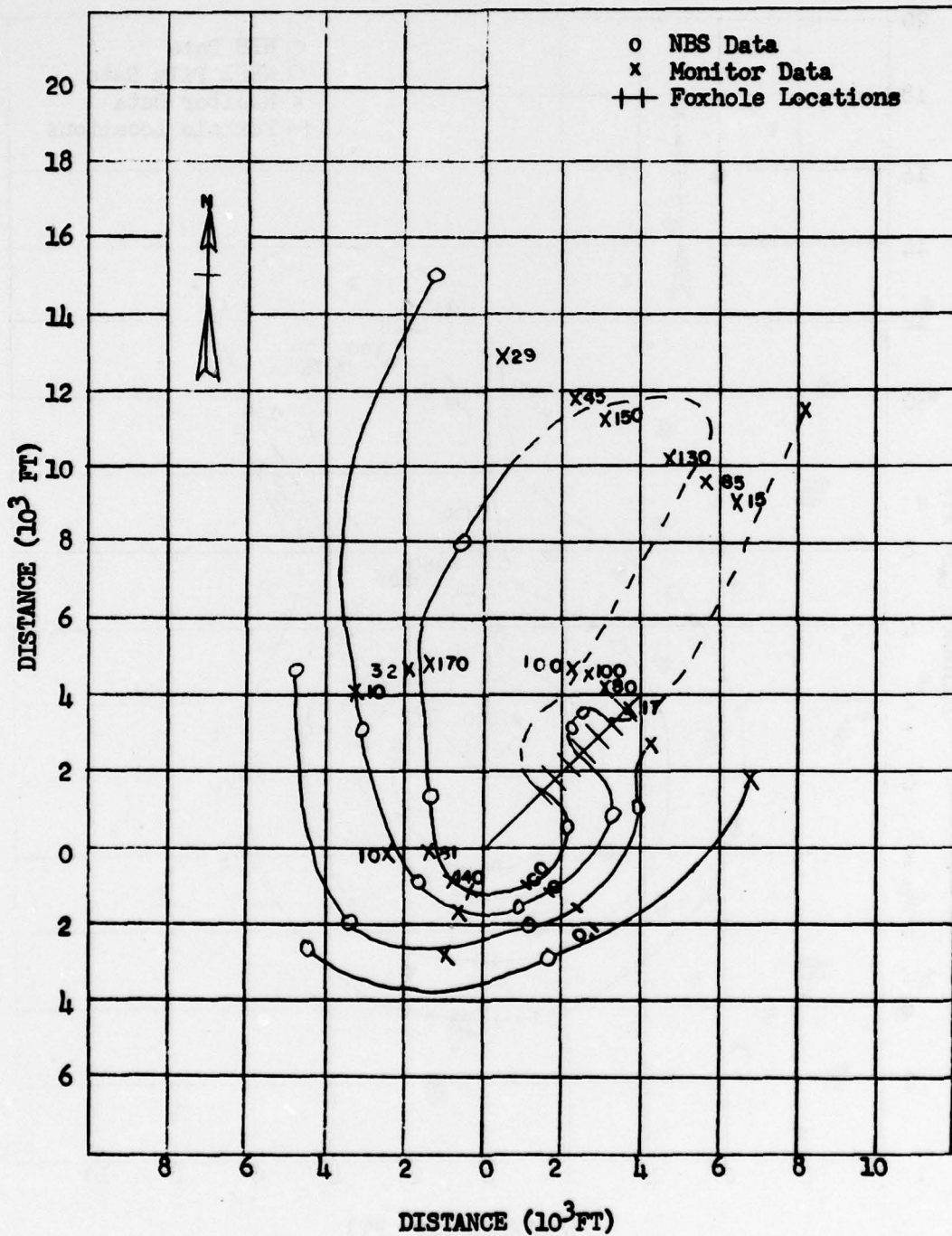

Fig. 3.3 Surface Burst, Iso-Dose Contours At 1 Hour

- 10 -

PROJECT 2.3-2

Fig. 3.4 Underground Burst, Iso-Rate Contours at 1 Hour

PROJECT 2.3-2
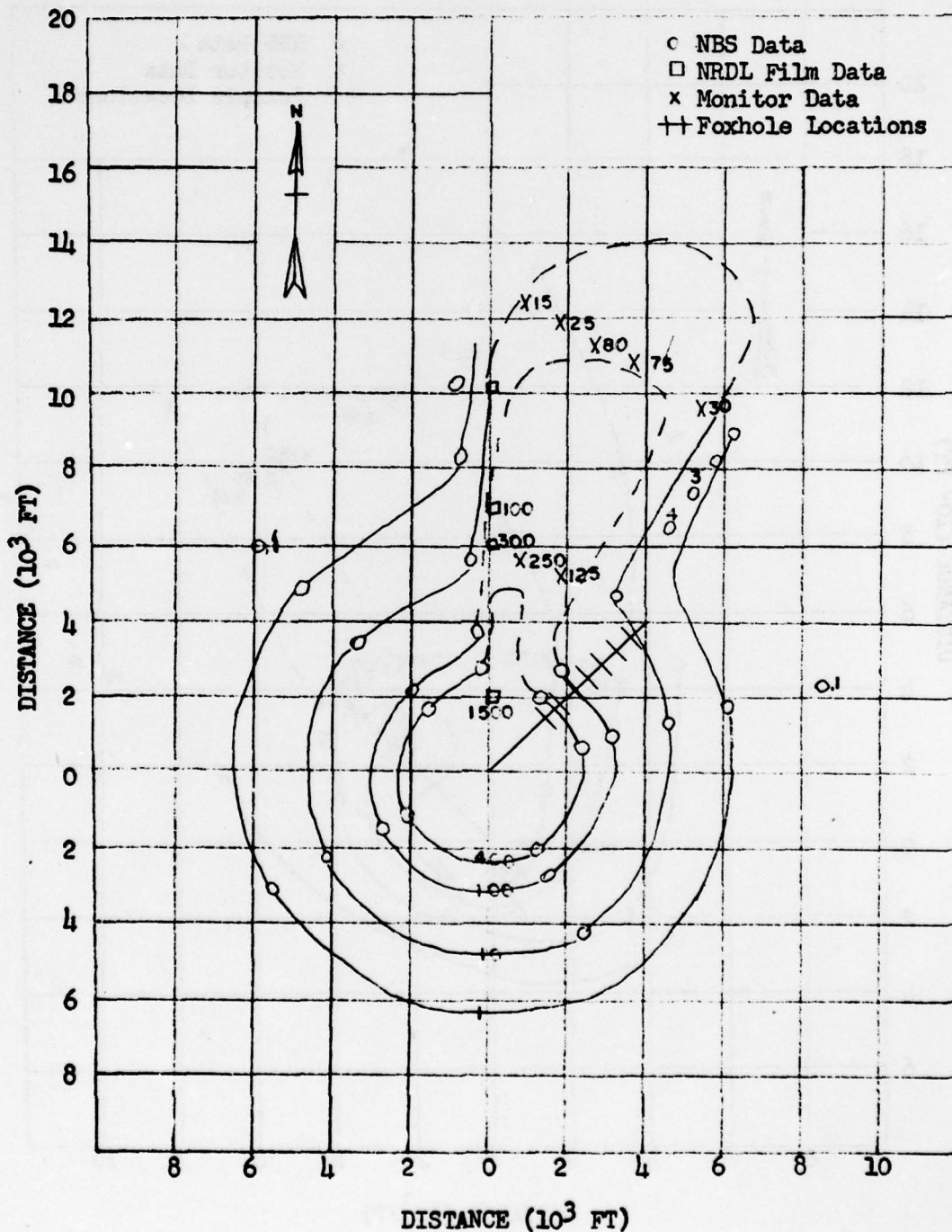

Fig. 3.5 Underground Burst, Iso-Dose Contours At 10 Minutes

- 12 -

PROJECT 2.3-2
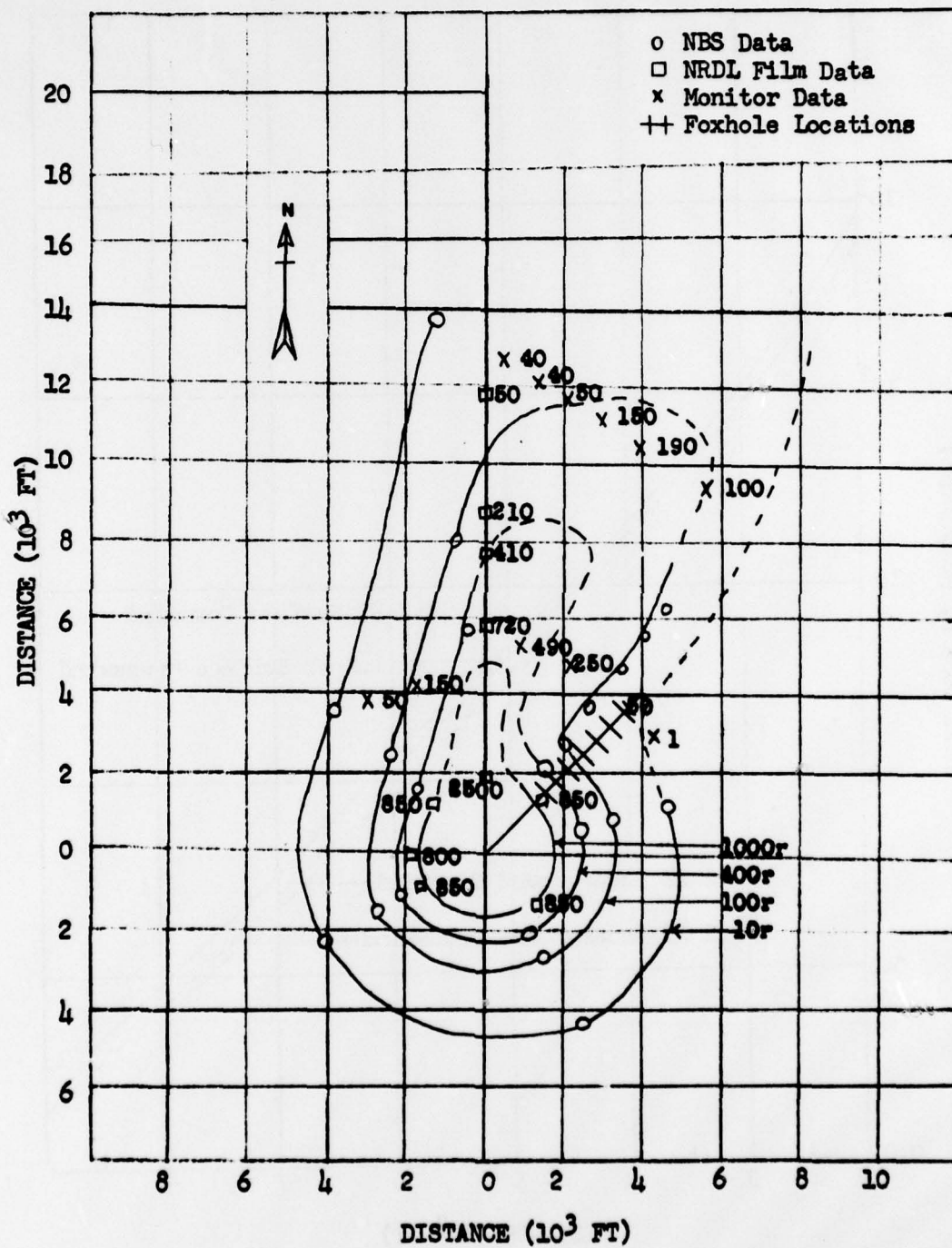

Fig. 3.6 Underground Burst, Iso-Dose Contours at 1 Hour

- 13 -

PROJECT 2.3-2
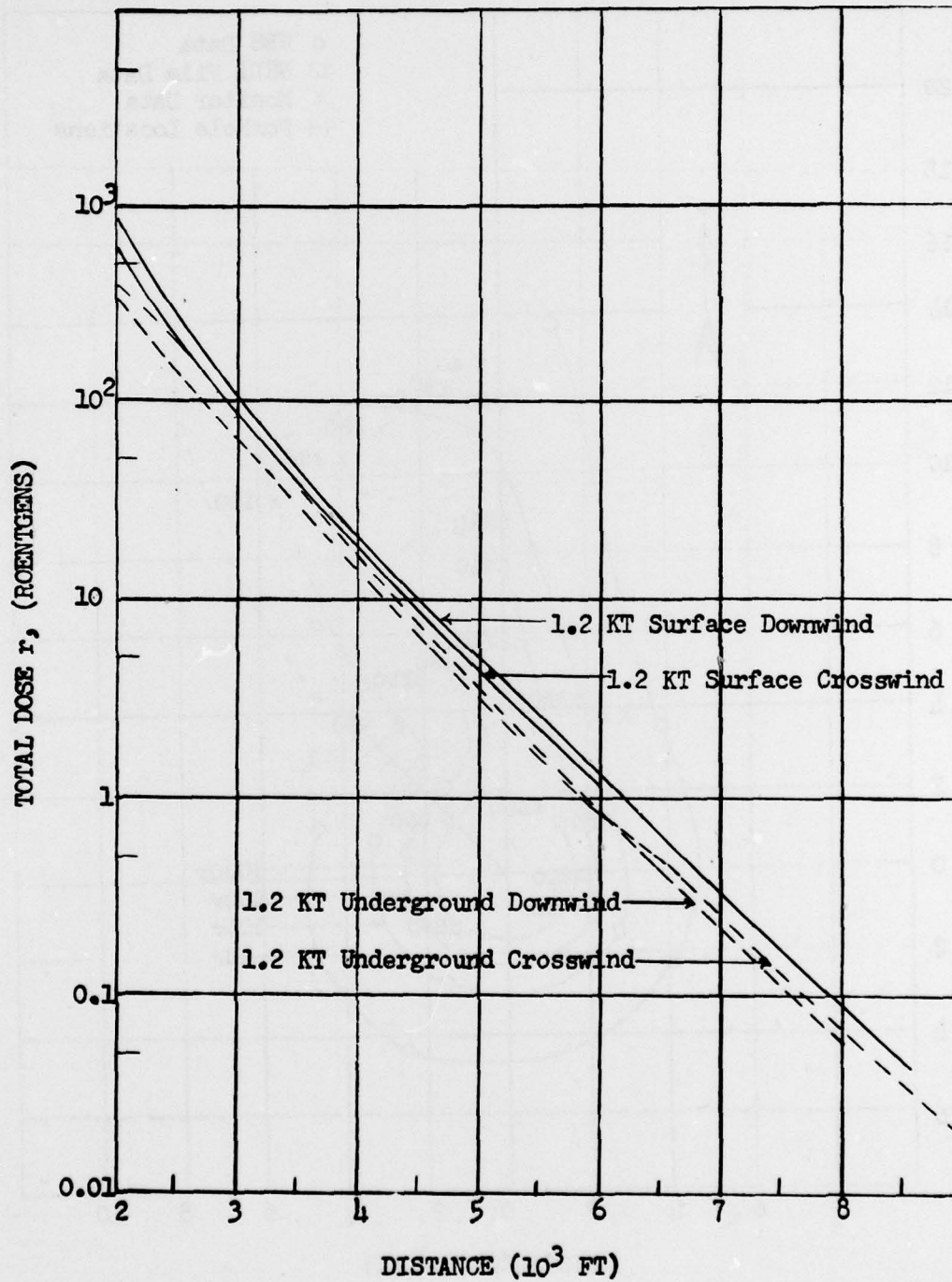

Fig. 3.7 Total Dose at 10 Seconds (Surface and Underground Bursts)

- 14 -

CHAPTER 4

DISCUSSION OF RESULTS

4.1 GAMMA DOSES FROM SURFACE DETONATION

The gamma doses recorded during the surface detonation are given in Table 3.1. The readings are consistent among themselves and can be easily interpreted from the contours and graphs given in Figs. 3.1 through 3.3 and 3.7. Consider the dose of 800r, measured 3 feet above the foxhole located 2000 feet from the detonation. Fig. 3.7 shows that the total dose to be expected at 2000 feet one hour after the burst was between 600 and 800r. Figs. 3.1 and 3.8 show that the contribution of residual activity to the total dose after one hour was small, approximately 15r. However, it must be remembered that the above illustration pertains to crosswind locations only; in the downwind direction surface total doses of about 800r were found as far as 7000 feet from the detonation at H+1 hours, (see Fig. 3.3).

The doses in the foxholes at locations below the surface fell off sharply from the surface values. Analysis of the data shown in Table 3.1 indicates that the doses at the bottom of the foxhole were primarily the result of the scattering of prompt radiation. For example, the average value of the films at the bottom of the foxhole 2000 feet from the surface shot was about 32r and the prompt radiation on the surface was 600r, (see Fig. 3.7). Therefore, about 5 per cent of the prompt surface radiation reached the bottom of the foxhole. The results from Operation BUSTER indicated that this dose was just about what should be expected from initial radiation at the bottom of two-man foxholes. Of course, if the foxhole were located directly downwind, the dose would be higher due to an increased amount of fall-out into the foxhole. However, as will be shown in the analysis of the results from the underground detonation, only the radioactive matter that fell into the foxhole contributed to the total dose, the radiation field on the surface surrounding the foxhole had very little effect on the doses at the bottom.

4.2 GAMMA DOSES FROM AN UNDERGROUND DETONATION

The doses received on the surface and in foxholes at various distances from the point of detonation are given in Table 3.2. With the exception of the 2000 foot station, all badges gave readings

consistent with the contours shown in Figs. 3.4 through 3.6. The
2000 foot station gave a reading of 3850r, considerably higher than
expected from the contours. However, examination of Fig. 3.6 shows
that although the total dose contours are accurate over large dis-
tances, small areas of very high activity existed in certain loca-
tions even though the surrounding areas gave relatively low radiation
doses. This was undoubtedly caused by the concentration of a large
amount of fall-out in these locations or by a higher specific contamina-
tion of the fall-out in that particular region. Consider the dose of
73r obtained 5000 feet from the burst. From Fig. 3.6 the total dose
after one hour at the distance should be about 20r. Figs. 3.4 and 3.7
show that the residual radiation after one hour added about 27r, for a
total of 57r. But, data from monitor readings as shown in Fig. 3.6
indicated that the total dose after one hour was 50r, instead of 20,
in the area where the 5000 foot station was situated. If the 27r resi-
dual radiation were added to this, the result would be 77r which is
very close to the reading obtained by the film.

Comparison of the results obtained during the underground burst
with those during the surface burst showed that the total gamma doses
were greater at all distances following the underground detonation.
The increase was due primarily to the greater amounts of radioactive
matter that fell from the floud. The doses dropped sharply beyond
2000 feet to reading of about 1000r at 2500 feet and 175r at 3000 feet,
(see Table 3.2). Consideration of the doses recorded at these stations
lead to an estimate of the effectiveness of foxholes as shields against
gamma radiation from an underground burst. In the 2500 foot foxhole,
a dose of less than 100r was measured at the bottom, while the dose 3
feet above the surface was approximately 1000r. Clearly, personnel on
the surface would be exposed to lethal doses while those protected by
foxholes would receive relatively unimportant doses.

Analysis of the doses obtained at the lower levels inside the
foxholes indicated that only scattered prompt radiation and radioactive
matter that fell into the foxholes contributed greatly to the measured
doses and that the attendant surface radiation field was relatively
unimportant. This conclusion arose from the fact that the films at
the bottom of the two-man and one-man foxholes received about the same
doses, see Table 3.2, although the one-man foxhole had only one-half
the area of opening. Therefore, if the column and cloud contributed
greatly to the doses at the bottom, a greater reading should be ex-
pected in the two-man foxhole. The same argument is true with respect
to the surface contamination surrounding the foxholes. If this con-
tamination contributed greatly to the doses inside the foxholes
through radioactive decay, then it should have a greater effect on
the badges in the two-man foxhole because of the greater opening.

PROJECT 2.3-2

This was seemingly not the case. Moreover, Reitmann of the Engineer
Research and Development Laboratories, stated in his report on Project
6.2, Land Reclamation, that less than 10 per cent of the surface
activity was found at the bottom of a 4 foot trench that was dug in a
contaminated area after the surface burst of Operation JANGLE.

CHAPTER 5

CONCLUSIONS

5.1   FOXHOLE SHIELDING OF GAMMA RADIATION

    5.1.1   Surface Detonation

        Standard foxholes provide excellent protection to
personnel from the gamma radiation emitted during the detonation of
an atomic weapon on the surface of the ground. The results from the
comparatively small sized weapon employed in Operation JANGLE show
that 2000 feet from the burst, the location of the closest foxhole
doses of about 60r were measured at the bottom of a foxhole, less
than 10 per cent of the dose measured 3 feet above the surface of the
ground. Due to the location of the foxhole in the crosswind direction,
the dose at the bottom was caused primarily by scattered prompt radia-
tion plus a small contribution from the residual activity of the fis-
sion products on the surface of the ground. In the downwind direction
there would be a contribution from matter that falls out from the
cloud into the foxhole in addition to the above mentioned. This fall-
out will depend on the wind velocity for a given sized weapon, and
although it is expected to increase the dose in the foxholes, es-
pecially in those located close to the detonation, it is relatively
unimportant in comparison to the prompt and residual activity since
it can be easily shoveled out of the foxhole in a short time.

    5.1.2   Underground Detonation

        With the possible exception of those located in the
area close to the point of detonation where extensive fall-out occurs,
foxholes also provide effective shielding in the case of an under-
ground detonation. Even within this area of extensive fall-out, which
at Operation JANGLE extended approximately 2000 feet, the high doses
recorded in the foxholes could be greatly reduced by digging out the
radioactive matter that fell into the hole. It is highly probable
that one-half the doses recorded in the foxholes located within 2500
feet of the detonation at Operation JANGLE were directly attributable
to this type of fall-out and most likely a higher percentage at dis-
tances greater than 2500 feet.

- 19 -

5.2   SOURCES OF RADIATION CONTRIBUTING TO DOSES

The doses obtained from the detonation of atomic weapons on the surface or underground receive contributions from prompt radiation, residual activity due to fall-out of radioactive matter, and possibly radiation emanating from the activity of the solumn and cloud.

5.2.1   Surface Detonation

The complete doses at the bottom of foxholes in this operation were attributable to scattered prompt radiation. No contribution from fall-out or cloud and column activity was evident but it is expected that fall-out would have increased the doses if the foxholes had been located in the downwind direction.

5.2.2   Underground Detonation

The greatest portion to the total dose measured at the bottom of foxholes apparently came from the fall-out matter in the foxhole. The contamination on the surface of the ground surrounding the foxhole contributes only about 10 per cent to the doses at the bottom and the prompt radiation could not contribute more than occurred in the surface burst since both weapons were the same size. Yet, in all cases the doses were considerably higher during the underground detonation leading to the obvious conclusion that matter falling into the foxholes played the most important role, also, the doses in the two and one-man foxholes were equal although the two-man foxhole had twice the opening area. If the column or cloud activity contributed greatly to these doses, it was expected that the doses in the two-man foxhole would be about twice as great as that in the one-man.